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THE APRIL SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

APRIL, 1933

The Scientific Work of the Government of the United States

SCIENTIFIC ASPECTS OF THE WORK OF THE DEPARTMENT OF STATE

PREPARED FOR THE SCIENTIFIC MONTHLY BY THE DEPARTMENT OF STATE OF THE FEDERAL GOVERNMENT

On July 27, 1789, President Washington approved an act entitled "An Act for establishing an Executive Department, to be denominated the Department of Foreign Affairs." As defined in this act, the functions of the new Department were confined exclusively to the management of foreign affairs; however, on September 15, 1789, a supplementary act was approved extending the functions of the Department into the domestic field and changing its name from the Department of Foreign Affairs to the Department of State.

In the early days of its existence, the Department had certain duties which, with the passage of time and the creation of new executive departments, have long since been transferred elsewhere. Several of these functions partook of a scientific character. Thus, by an act of April 10, 1790, the Department of State was given control over patent matters. At first, patents were granted by a Board, composed of the Secretary of State, the Secretary of War, and the Attorney General; but in 1793, another act relating to patents was passed abolishing the Board and placing the Secretary of State alone at the head of the Patent Office. This arrangement held good until 1849 when, with the establishment of the Department of the Interior, control over patent matters passed to that Department.

From 1790 until 1850, or for a period of 60 years, the Department of State supervised the taking of the decennial census. In the latter year, this work also was transferred to the newly created Department of the Interior, whence it was again transferred to the Department of Commerce and Labor only to come to rest at last in the Department of Commerce.

Another of the early duties of the Department was the management of the mint. Mr. Jefferson, early in his tenure as Secretary of State, transmitted to the President for his consideration two experimental coins made "by putting a silver plug worth three-quarters of a cent into a copper worth one-fourth of a cent." In view of the variety of these duties, one can understand Jefferson's remark that the Department of State embraced "the whole domestic administration (war and finance excepted)."

But these early activities, while interesting to recall, no longer form a part of the work of the Department, which, though still retaining some duties of a domestic character, is now, as was orig-

inally intended, almost exclusively concerned with the management of the country's foreign relations. The term "foreign relations," however, is a very comprehensive one and includes within its scope relations concerning problems of a scientific nature as well as those touching on economic or political matters.

The Department of State, unlike certain of the other executive departments, is not engaged directly in scientific pursuits. Its activities in behalf of science arise largely, though not exclusively, first, from the fact that the Government of the United States contributes an annual quota toward the maintenance of a number of international bureaus or commissions located abroad, about half of which are concerned with work of a scientific nature and, secondly, from its duties in connection with the many international conferences or congresses, a large percentage of which are of direct interest to science in one field or another.

Included among the international scientific agencies to which this Government contributes is the International Bureau of Weights and Measures. The work of this Bureau, which is located at Paris, consists in making all comparisons and verifications of the standard meter and kilogram. It has the custody thereof and makes other comparisons and verifications dealing with weights, measures and electrical units. The international meter and kilogram, adopted by the Treasury Department in 1893, are the basic standards of length and mass in the United States. The instruments of the Bureau of Standards at Washington are copies of those kept by the International Bureau of Weights and Measures and are sent from time to time to Paris for comparison with the originals, thus maintaining a constant standard in this country for instruments used in boundary measurements, surveys and triangulation.

This Government has also maintained membership for many years in the International Institute of Agriculture, an institute located at Rome which furnishes member states with data on the various factors determining the prices of agricultural produce in the world's markets, and acts as a clearing house for information on economic, scientific and technical problems affecting world agriculture.

Similarly, support is given to the Pan-American Sanitary Bureau and the International Office of Public Health. Both agencies are concerned primarily with the problem of the international control of communicable disease, the sphere of action of the former being North and South America, while the latter is most directly interested in the problem so far as it affects the countries of Europe.

Under authority of an Act of Congress, approved on May 7, 1928, the United States through the Department of State contributes an annual sum to the Gorgas Memorial Laboratory. This laboratory is maintained in connection with the Institute of Tropical and Preventitive Medicine, the seat of which is at Washington, and constitutes a center for research in the field of tropical disease.

The International Hydrographic Bureau, with headquarters at Monaco, performs an important function in effecting a close and permanent association between the hydrographic services in the adhering states. It aids in coordinating their efforts and facilitates the adoption by national hydrographic offices of resolutions taken by the international hydrographic conferences which meet from time to time. It seeks to obtain uniformity, so far as is possible, in hydrographic documents and furthers in many ways progress in the theory and practise of the science of hydrography.

Another of these international scientific bureaus, the American International

Institute for the Protection of Childhood, was established in 1927 as a consequence of the Pan-American Child Welfare Congress held in Santiago, Chile, in 1924. It has for its object the collection and publication of laws, regulations and other documents concerning the protection of children; the publication of official reports and studies concerning the interpretation and execution of such laws; the collection of records of organizations and institutions pertaining to children; and the recording of statistics, charts and general conclusions.

This Government contributes also toward the expenses incurred by the Central Bureau of the International Map of the World, a bureau located at Southampton, England, having for its purpose the standardization of a world map. The Bureau publishes an annual report made by each of the member states as to the compilation and publication of sheets conforming to the standard specifications, besides providing a medium for the exchange of information of value to the adhering countries.

The Permanent International Association of Road Congresses, with offices at Paris, was established in 1908 and consists of delegates of governments and organizations of all countries subscribing annually to its support, of which the United States is one. The object of the association is to promote progress in the construction, traffic and exploitation of roads by organizing periodic international road congresses; publishing papers, proceedings and other documents; and by collecting and disseminating the results of tests, both road and laboratory, of materials used in road construction and maintenance.

Of particular interest to scientists is the International Commission on Annual Tables of Constants, to which this Government has contributed annually for a great many years. The work of this commission consists in the collection and annual publication in tabular form of the quantitative results of research in chemistry, physics, biology, and applied branches. It is obviously important that the same constants be used in all countries in order that scientific and technical papers and reports may be understood in other countries than those in which they are published. Any new values which are determined are collected by the International Commission and made available in the annual tables.

Mention should also be made of the International Council of Scientific Unions, established at Brussels. The following list of member societies indicates the wide range of problems in the purely scientific field dealt with in the council: The International Astronomical Union; the International Union of Chemistry; the International Union of Geodesy and Geophysics; the International Scientific Radio Union; the International Union of Physics; and the coordinating agency in International Council of Scientific Unions. In view of the fact that scientific investigation is being carried forward along like lines in many countries, it is obviously in the interest of both economy and progress in research that the investigations be coordinated and their results disseminated to scientists throughout the world.

The rapid strides made in comparatively recent years in improving and expanding the world's communication and transportation services have resulted, among other things, in bringing home most effectively to the nations of the world the fact of their essential interdependence. This realization has in turn brought about quite naturally a marked increase in the number of international conferences of which a very considerable number are concerned with scientific problems.

Taking, for example, the period from July 1, 1929, to June 30, 1932, out of 160 conferences in which this Government participated officially, 69 met to

discuss questions of direct scientific interest. It would obviously be impossible within the limits of this article to mention in detail all of these. Some idea, perhaps, of the wide range of subject-matter covered in these meetings can be gained from the following list of conferences taken more or less at random from among those held recently: Ninth International Horticultural Congress; Fifth International Botanical Congress; Eleventh International Congress of Zoology; Inter-American Conference on Agriculture; Fourth International Congress of Geometricians; Third International Conference for Photogrammetry; Eighth Congress of the Far Eastern Association of Tropical Medicine; Fifteenth International Congress of Agriculture; Sixth International Congress of Military Medicine and Pharmacy; Eighteenth International Congress of Orientalists; International Congress of Geography; Second Congress of Comparative Pathology; and Third International Hydrographic Conference.

Among conferences of a scientific character scheduled to convene in the near future are the Sixteenth Session of the International Geological Congress, which will meet in Washington this coming June; the Seventh International Congress of Military Medicine and Pharmacy, to convene this summer at Madrid; the Fourteenth Concilium of Ophthalmology; and the Fifth Pacific Science Congress, scheduled to be held in Victoria and Vancouver, British Columbia, in June of this year.

Geography is a science which, since 1920, has been directly recognized in the organization of the Department of State. The Office of the Geographer, besides compiling maps, some of which have been published by the Department—notably those of Manchuria and China—is responsible for the geographic phases of all matters under consideration by the Department. From time to time, however, special studies are required, such as the historical and geographical study made in connection with the determination of the national origin immigration quotas, now in effect. These researches which extended over a period of three years were necessary in order to bring the statistical tables of the United States Census into conformity with the present-day boundaries in Europe. The Office of the Geographer was also concerned in the preparation of the "First Report on Foreign Geographic Names," published by the United States Geographic Board in 1932.

The Department of State is frequently called upon to assist in making the necessary arrangements for American institutions to carry on scientific explorations and researches in foreign countries. Among the more recent expeditions of this sort facilitated by the Department might be mentioned the present exploration being carried on in the West Atlantic Deeps by the Smithsonian Institution, under the direction of Dr. Paul Bartsch; the International Scientific Expedition to the Bahamas in 1932, under the auspices of Princeton University; and the Botanical Expedition to Colombia, composed of representatives of the Johns Hopkins University and the University of Pennsylvania.

This article would scarcely be complete without at least reference to the work of the American consular and diplomatic officers in sending to the Department reports on the results of scientific investigations being carried on abroad and on matters of general scientific interest, reports which the Department transmits to interested departments of the Government as well as to private organizations concerned.

RESEARCH WORK OF THE BUREAU OF RECLAMATION

By Dr. ELWOOD MEAD

COMMISSIONER OF RECLAMATION, UNITED STATES DEPARTMENT OF THE INTERIOR

THE Bureau of Reclamation of the Department of the Interior was established by the Reclamation Act of June 17, 1902. By this act, revenues received from the sale and disposal of public lands in the Western states were set aside in a special fund known as the Reclamation Fund to be used in the construction of irrigation works for the storage, diversion and distribution of water for the reclamation of arid and semi-arid lands in the West. The Reclamation Fund is a revolving fund, and the expenditures from it for constructing irrigation works, including costs of surveys and investigations in connection with such works, become a charge against the lands benefited which must be repaid by the owners of these lands over a period not exceeding forty years.

During the thirty years of its life, the bureau has examined and surveyed numerous irrigation projects located throughout the seventeen Western states, and has constructed and operated in whole or in part thirty-two adopted projects. Many features in the design and construction of these irrigation projects have involved unprecedented dimensions, conditions and methods, and have led into fields of engineering of a pioneering nature. The engineers of the bureau have often found that previous theory, practice and experience in design and in construction methods were inadequate. Such findings have emphasized the need for constant research and investigation into new methods of design and construction. These researches and investigations have been conducted as thoroughly and extensively as possible, but due to the limitations of available funds they have not been as complete or extensive as desirable. Practically no funds have been available for pure research work, and as all expenditures from the Reclamation Fund are reimbursable the money expended for research investigation must in every case be restricted to the amount which can properly be charged to the design or construction of the particular project or feature for which the work is undertaken.

The irrigation projects of the bureau involve a great variety of construction work, including storage dams and diversion dams of many different types, power plants, pumping plants, canals, laterals, drains, conduits and canal structures of all kinds. The successful and economical design, construction, operation and maintenance of such works is greatly aided by proper engineering research. Likewise the determination of the economic feasibility of proposed irrigation projects is of prime importance and involves much work of a research nature, including investigations of the quality of soils, sufficiency of water supply, suitability of climatic conditions and the value of crops.

Many notable engineering works have been constructed on the completed projects, including several of the outstanding dams of the United States. Among these structures, constituting a progressive succession of the highest dams in the world, are Shoshone Dam in Wyoming, 328 feet high, and containing 78,600 cubic yards of concrete, which was completed in 1910; Arrowrock Dam in Idaho, 349 feet high, and containing 585,000 cubic yards of concrete, which

was completed in 1915; and Owyhee Dam in Oregon, 405 feet high, and containing about 536,000 cubic yards of concrete, which was completed in 1932. The bureau now has under construction the Boulder Canyon Project, the outstanding feature of which is Hoover Dam on the Colorado River near Las Vegas, Nevada, which will rise 730 feet above bedrock, or nearly twice as high as any previous dam, and with appurtenant works will contain about 5,000,000 cubic yards of concrete. As this project involves the most extensive and complete program of investigation and research yet undertaken by the bureau, this article will be largely confined to a description of the research work undertaken in connection with the design and construction of Hoover Dam and appurtenant works.

The Boulder Canyon Project

The conquest of the Colorado River which has culminated in the construction of Hoover Dam had its inception four hundred years ago when, in 1536, Cortez pawned his wife's jewels for necessary funds and sent Francisco de Ulloa to find the fabled seven cities of Cibola. Ulloa reached the mouth of the Colorado River in 1539 but there abandoned the search because of the thirty-foot tides which, as he recorded, "rush with great rage into the land." The actual discovery of the Colorado River took place in 1540 when Alarcon entered the river at its mouth and ascended it in boats for fifteen days. After this visit the assault on the river remained dormant for over three hundred years, except as it was touched by occasional Spanish explorers searching for routes to California and to the interior.

In 1857 Lieutenant Ives, of the Engineer Corps of the U. S. Army, attempted to prove the navigability of the river in the hope that it could be used for carrying supplies to the military posts at Salt Lake City, Utah, and Tucson, Arizona. Starting in March, it was December when his steamboat *Explorer* reached the swift waters of Black Canyon, the site of Hoover Dam. After spending five days in traveling the last twenty miles he accepted Black Canyon as the ultimate head of navigation.

In 1869 Major John Wesley Powell, of the Geological Survey, made the first comprehensive exploration of the Colorado River and demonstrated the possibility of passing alive through the 1,000-mile stretch of heretofore impassable canyons. With the passage of the Reclamation Act in 1902, detailed investigations of the Colorado River were inaugurated, which were in succeeding years extended to cover the entire basin, with a view to disclosing all possibilities of water utilization for irrigation, flood control and power as a basis for a comprehensive plan of development. By 1924 the investigations had been completed far enough to demonstrate conclusively that the first major project in the control and development of the river should include the construction of a high dam in Black Canyon, which is twenty miles downstream from the site first investigated in Boulder Canyon, from which the project derives its name. This dam and reservoir will accomplish the fourfold purpose of flood control, storage of water for irrigation, removal of silt and power development. (Fig. 1.)

The undertaking of the Boulder Canyon Project under the direction of the Reclamation Bureau was authorized by the Boulder Canyon Project Act, which was signed by President Coolidge on December 21, 1928. This act authorized an appropriation of $165,000,000 for the construction of: (a) A dam in Boulder or Black Canyon to store not less than 20,000,000 acre-feet of water; (b) a power plant, and (c) an All-American canal to connect the Colorado River with Imperial Valley. A fund known as the Colorado River Dam Fund, and separate

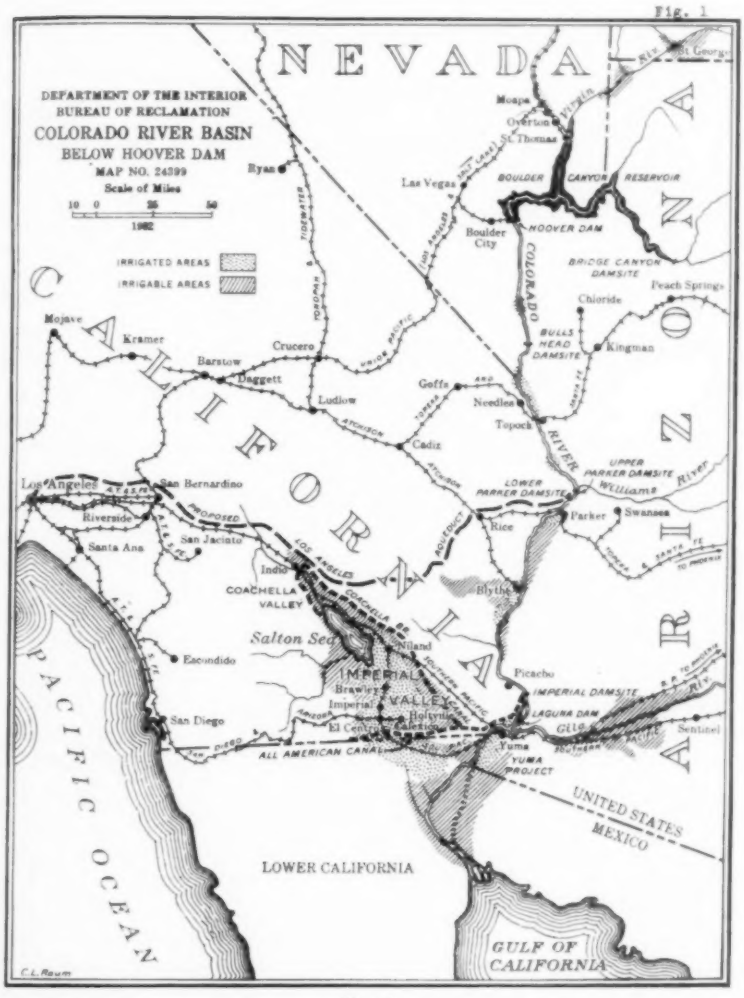


FIG. 1.

from the Reclamation Fund, was set up to finance the construction of the Boulder Canyon Project. The act provided that before actual appropriations could be made, contracts for the sale of power and water must be secured to insure payment of the cost of the dam and power plant with 4 per cent. interest in not more than fifty years.

All requirements of the act having been met, the initial appropriation for construction of the project was approved by President Hoover on July 3, 1930. This date marks the beginning of a new epoch in the history of the Bureau of Reclamation. During the first twenty-seven years of its activities the bureau had designed and constructed over one hundred dams, of constantly increasing importance, in addition to many other great engineering works. The Owyhee Dam might be considered as climaxing this progression in the construction of important though not extraordinary engineering works. The intrusting of the design and construction of Hoover Dam

to this organization places new and greatly increased responsibilities on the engineers of the bureau and marks a new chapter in the history of the design and construction of high concrete dams.

Nearly all the dimensions of Hoover Dam and its appurtenant works are of unusual magnitude, presenting many unusual problems that must be solved in the design, construction and operation of the project. Great caution must be exercised in applying previous theories and practises to the design and construction of a dam of these unprecedented dimensions. New theories and practises must be developed from fundamental data, and these must be checked, tested and proved in every possible way to insure that no mistakes are made in their development or application, and that the maximum economy is secured that is consistent with permanence and absolute safety. Recognizing these conditions, and considering the importance of the structure and the enormous expenditure involved, it was deemed imperative that a sufficient research program be undertaken to establish beyond question the suitability and sufficiency of the methods of design and construction to be adopted.

The research program for Hoover Dam is now in progress in nearly all its features, and while tentative conclusions have been formulated as the progress of construction has demanded, the final results and conclusions are not yet available for publication. It is possible, however, at this time to outline the purposes and scope of the investigations, which involve researches in many branches of science, including mathematics, mechanics, physics, hydraulics, seismology, structural geology, chemistry and related sciences. New methods and equations for the mathematical analysis of stresses have been developed from fundamental principles. New features of mechanical, structural and hydraulic design have been adopted. Improved methods and technique in model testing have been worked out. Exhaustive studies have evolved new concepts of the structural and thermal properties of concrete, including the development of new specifications for Portland cement of controlled heat evolution, and many experiments and tests have been made under both laboratory and actual field conditions, to determine physical, structural and hydraulic properties.

Design of the Dam: Hoover Dam will be of the massive arch-gravity type, about 730 feet high and 650 feet thick at the base. (Fig. 2.) The pressure of the water on the upstream face at the base of the dam will be about 45,000 pounds per square foot, and the total pressure on the upstream face will be more than three and one fourth million tons. This pressure will be transmitted to and supported by the rock of the canyon walls, and of the foundation under the dam. Under such conditions the amount and distribution of the stresses in the dam as well as in the abutments and foundations must be known with certainty and the structure must be so proportioned as to support these tremendous loads with maximum safety and economy and with no possibility of destructive stresses being developed.

While the technical design of the dam is largely a matter of mathematical analysis, supplemented by model testing, it involves at the same time many problems of a research nature. Until recent years no adequate and satisfactory method of analyzing the stresses in massive arch dams was known. The trial load method of analysis, which is now widely accepted as the best available method, has been gradually evolved by the engineers of the bureau, and this method has recently been brought to a highly satisfactory working state in connection with the design of Hoover Dam. The accuracy and dependability of this method of analysis has been established by field observation and particularly by model tests, which have proved conclu-

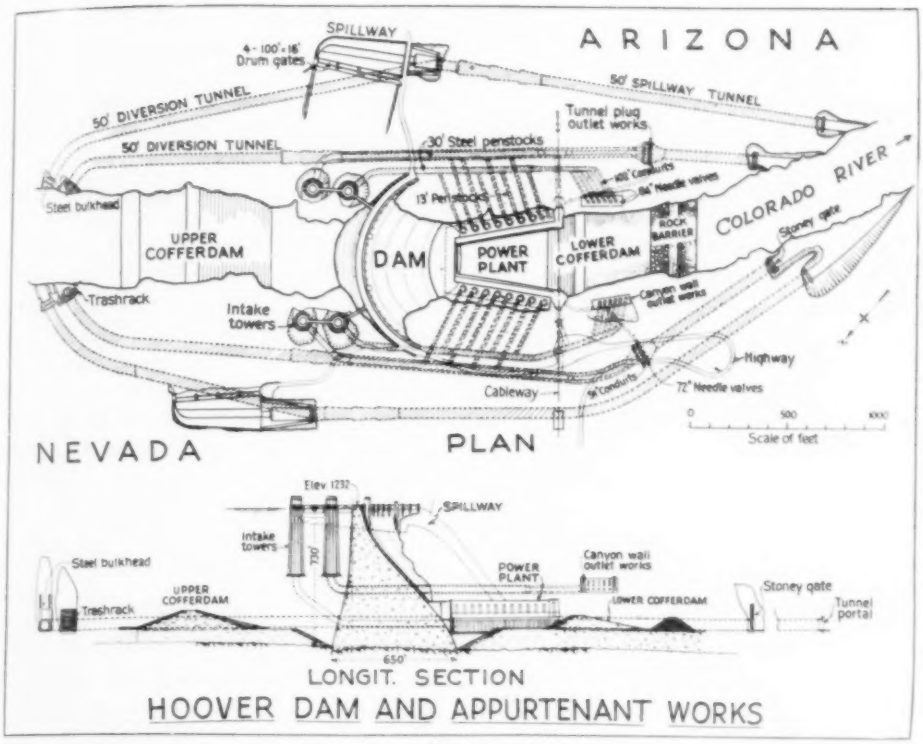


Fig. 2.

sively that the computed arch action takes place in a massive arch-gravity dam of the type selected. (Fig. 3.)

The effect of internal temperature variation, shear, twist, flow under stress, Poisson's ratio, foundation and abutment deformation, radial cantilever sides, uplift pressure at the base, uplift pressure in the pores of the concrete, earthquake shock, spreading of canyon walls due to reservoir water pressure, and similar phenomena, have been analyzed and determined. The magnitude and distribution of stresses in all parts of the foundation and abutments under all conditions of loading have also been determined. The effect of non-linear distribution of stress in all parts of the structure, in both arch and cantilever elements, has been evaluated. The stress conditions caused by the sub-cooling of the concrete during the hardening period, by pressure grouting of the construction joints and by other load conditions to be encountered during the construction period, have been investigated. These analyses and determinations have required extensive researches into the fundamental theories of mechanics and elasticity and into the complete field of stress analysis.

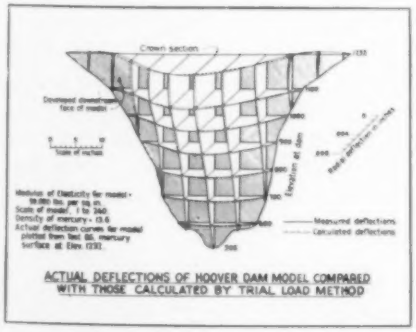

Crown section
Measured deflections
Calculated deflections
ACTUAL DEFLECTIONS OF HOOVER DAM MODEL COMPARED WITH THOSE CALCULATED BY TRIAL LOAD METHOD

Fig. 3.

The original program of arch dam model testing that was started several years ago in cooperation with the Engineering Foundation Arch Dam Committee has been considerably extended in connection with Hoover Dam. It includes extensive research and investigations to determine the best and most suitable materials for use in models of this kind, including means of load application, and methods and technique in measuring and analyzing the resulting stresses and strains. The testing program included the building, testing and analyzing of a concrete model of the Stevenson Creek test dam, a concrete model of the Gibson Dam and a plaster of Paris and celite model of Hoover Dam. It also includes the construction and testing of a soft rubber model of Hoover Dam.

While these tests and analyses have not as yet been completed in all respects, the results so far accomplished have conclusively shown that arch action will take place as computed, and that the adopted design and dimensions of the dam are economical, adequate and entirely safe for all conditions of loading to be met.

Cement and Concrete Research: The science and art of concrete design and construction has received a great amount of study by many able scientists and investigators during the past two decades, and much progress and many improvements have been made. These studies have, however, been largely confined to ordinary concrete construction in which the maximum size of aggregate is about 1½ inches in diameter. Massive concrete in large dam construction, where the dimensions of the concrete structure are of the order of several hundred feet, and where the aggregate varies in size from fine sand to cobbles as much as nine inches in diameter, presents problems in design and construction that have not heretofore been satisfactorily solved. The results of past research in concrete, while valuable, and applicable in varying degree to all concrete work, do not furnish adequate data for the solution of these new problems. Although many concrete dams have been built regardless of the lack of complete data, the unprecedented magnitude of Hoover Dam and the requirement for absolute safety and permanence in this monumental structure make the solution of these mass concrete problems correspondingly more important than in any dam heretofore constructed. These problems must be thoroughly investigated and any fundamental data, now lacking, that are required for their solution must be secured, which is the main purpose of the program of concrete research.

The major portion of the concrete research program relates to the phenomena of heat generation in concrete during the hardening period, which are the cause of volume changes in the concrete. The control of volume changes is of utmost importance in a massive concrete structure such as Hoover Dam, which will be subjected to enormous water loads, and whose mass must be continuous in order to provide not only for watertightness but also for the proper distribution of stresses throughout the structure. The law of heat dissipation or cooling of masses is that the time required for cooling of similar shapes is proportional to the square of the dimensions. For instance, a concrete structure fifty feet thick will lose 90 per cent. of its temperature rise in one and one half years, whereas a structure five hundred feet thick will require one hundred and fifty years to lose the same proportion of its temperature rise. If Hoover Dam were built without control of the rate of placing and without special provision for cooling the concrete, the setting heat would probably not be dissipated for several hundred

years, during which time destructive volume changes would take place, resulting in undesirable and possibly dangerous open joints or cracks in the mass.

These conditions have necessitated two new and special provisions in the design of the dam: first, circumferential construction joints in addition to the usual radial contraction joints, thus dividing the mass into a series of approximately square columns or blocks; and, second, a complete artificial cooling system consisting of pipes embedded in the concrete through which cold water will be circulated. This system will lower the temperature of the concrete to normal and cause the resulting volume change to take place during the construction period, so that the joints between the columns, which will be opened as the concrete cools and contracts, may be completely and permanently filled with cement grout forced into place under pressure before the structure is placed in service.

In order that these problems may be intelligently studied and efficiently solved, extensive pioneer research pertaining to the thermal properties of cement and concrete is required. All properties of cement, both chemical and physical, must be exhaustively studied in order that a type of cement with controlled and known heat evolution may be specified. The researches into the properties of cement are being carried on under a cooperative agreement with the University of California at the Engineering Materials Laboratory of the University at Berkeley, where necessary special facilities and trained personnel are available for this work. The principal cement companies of Southern California are also cooperating generously in this work.

The cement investigations involve a study of 94 different cements, including tests on more than 15,000 specimens. Of the cements being investigated, 28 are commercially ground; 22 are laboratory ground from commercial clinker; 20, covering an extreme range of chemical composition, are laboratory ground to equal fineness; and 24 are laboratory cements, laboratory ground to varying controlled degrees of fineness, from clinker of different chemical composition and different processes of clinker heat treatment. The investigation includes exhaustive studies of the effect of chemical composition; fineness of grinding; and, to a limited extent, the effect of manufacturing processes upon heat generation, volume changes, strength and durability. These cement studies are being supplemented, and will be concluded, in so far as Hoover Dam is concerned, by a series of tests on mass concrete now in progress at the Bureau of Reclamation laboratories in Denver, Colorado. Ultimately the three most promising cements will be further tested in the bureau's laboratories for temperature rise, volume changes and elastic and plastic properties. The studies thus far completed have indicated which of the cements tested have the most favorable characteristics and have made it possible to prepare and issue tentative specifications for the cement for Hoover Dam.

Researches being made into the thermal and related properties of concrete include the determination of the values of the thermal properties involved in the design of the cooling system; the practicability and efficiency of the cooling system as a whole; the determination of the rise of temperature that will take place in the interior of the dam; and the amount of heat that must be removed by the cooling system. Theoretical computations and laboratory tests are being supplemented by studies of the available records of heat development and volume changes in concrete dams previously built, and by specially

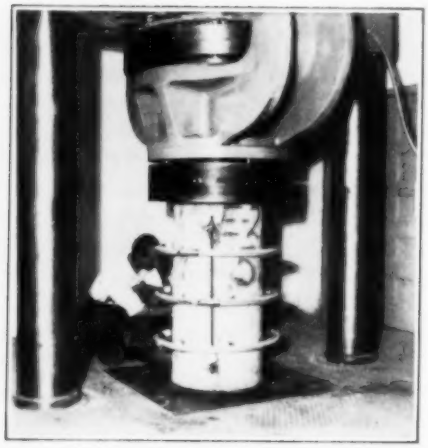


FIG. 4. TESTING 24″ x 48″ CONCRETE CYLINDER FOR MODULUS OF ELASTICITY AND POISSON'S RATIO IN 4,000,000 LB. CAPACITY HYDRAULIC TESTING MACHINE. DENVER LABORATORY.

planned field tests on the concrete in Owyhee Dam. These tests were started while the dam was under construction and will be continued throughout the cooling and pressure grouting periods.

Corresponding studies and researches are being made to determine the volume changes that will actually take place in the mass concrete of Hoover Dam. Concrete cores across contraction joints have been drilled in the interior of Gibson Dam, from which the actual joint opening and the efficiency of the pressure grouting could be determined. Special instruments have been developed and installed in the mass concrete of Owyhee Dam to accurately measure the volume changes that take place. Large size laboratory tests are being conducted in Denver to determine the efficiency of pressure grouting in closing contraction joint openings in mass concrete and to determine the desirable size of the joint openings and the properties of the cement grout required for efficient grouting.

FIG. 5. FAILURE OF 36″ x 72″ CONCRETE CYLINDER UNDER COMPRESSIVE LOAD. NOTE LINES OF CONICAL FRACTURE. DENVER LABORATORY.

Other problems included in the concrete research program are tests of ultimate compressive strength; long time measurements of plastic flow under stress; determinations of modulus of elasticity and Poisson's ratio; tests of sliding friction, strength of bond at horizontal construction joints, comparative strength of test cylinders of different sizes, variation in strength with ages and curing temperatures, proper gradation of aggregates through a range of sizes up to cobbles nine inches in diameter, effect of vibration of fresh concrete and permeability of concrete.

The concrete research program has required the establishment of two large, adequately equipped laboratories in Denver. (Figs. 4, 5, 6.) Test specimens of concrete in great numbers, varying in size from three inches in diameter by six inches in length to 36 inches in diameter by 72 inches in length, are required to be manufactured and tested. A 4,000,000-pound hydraulic compression testing machine was purchased and installed for this work in cooperation with the Bureau of Standards. The successful development of the many new and ingenious instruments and special fabricating and handling equipment, together with the technique necessary for carrying out these unprec-

edented tests, has been an important part of the work, but these details can not be described in the space allotted for this article.

Hydraulic Research: In the design and construction of its irrigation works, the bureau has on many occasions been confronted with the need for more thorough research in the field of hydraulics, and it has contributed in every way possible to the sum total of the knowledge now available in this branch of engineering science. During recent years the bureau has carried on a series of hydraulic model tests at the hydraulic laboratory of the Colorado Agricultural College at Fort Collins, Colorado. The data developed by these tests have proven valuable and conclusive in connection with the design of a number of outstanding hydraulic structures, including the spillways for Cle Elum Dam, under construction in the State of Washington, for Owyhee Dam in Oregon, and for Madden Dam in the Panama Canal Zone. The usefulness and indispensability of these and similar model tests in the efficient and economical design of large hydraulic structures, especially where unusual types or unprecedented dimensions and discharges are involved, have been fully demonstrated.

The enormous volumes of water that must be handled in the operation of Hoover Dam, together with the high heads involved, present extraordinary problems of design and construction. Hydraulic model testing is therefore being fully utilized in the design of the spillways and outlet works to supplement the theoretical hydraulic computations. The smaller scale model testing is being conducted in the Fort Collins laboratory. In so far as feasible, models of the same structure on two or more different scales are built and tested to better establish the similitude between the model tests and the performance of the prototype. A limited number of relatively larger scale model tests, wherein the required dimensions and volume of water are beyond the facilities available at Fort Collins, are being conducted in a field laboratory established on the main canal of the Uncompahgre Project, near Montrose, Colorado. Tests to determine the resistance of concrete surfaces to erosion under high velocities were also made under simulated actual conditions at Guernsey Dam on the North Platte Project, near Guernsey, Wyoming.

FIG. 6. BATTERY OF INSTRUMENTS FOR AUTOMATICALLY CONTROLLING TEMPERATURES IN ADIABATIC CALORIMETER ROOMS. DENVER LABORATORY.

Hoover Dam is being built in a relatively narrow boxlike canyon with solid rock walls rising nearly vertically to the top of the dam and steeply for several hundred feet above. The hydro-electric power plant must be placed in the bottom of the canyon immediately below the dam, and will extend across the downstream toe of the dam and along the foot of the canyon wall on each side of the river for about 600 feet. The spillways will provide for a maximum

flood discharge of 400,000 second-feet. These conditions, together with the great height of the dam, dictated the adoption of spillways discharging through inclined tunnels excavated in the canyon walls rather than the more common types, where the water discharges over the dam or through separate open channels.

Two spillways of similar design, each with a designed capacity of 200,000 second-feet, will be provided, one being placed in the canyon wall at each end of the dam. The crest structure will consist of an overflow weir parallel to the canyon wall and controlled by four automatic floating drum type steel gates, each 100 feet long by 18 feet high. The water will discharge over the crest into a parallel channel excavated in the canyon wall and then turn at right angles to enter a steeply inclined funnel-shaped tunnel whose diameter decreases gradually to 50 feet. Each inclined spillway tunnel connects at river level with one of the 50-foot horizontal tunnels used for river diversion purposes during the construction of the dam, and the water will be discharged through these tunnels into the river about 2,000 feet downstream from the dam. When discharging at the designed capacity, the energy of the water that will pass through the spillways falling nearly 600 feet will be equivalent to approximately 22,000,000 horsepower and the water will attain a velocity of about 175 feet per second or 120 miles per hour. The dissipation of this tremendous energy without destructive effects has presented problems calling for thorough study and research.

Numerous variations in the details and proportions of the crest structure, gates, open channel and inclined funnel-shaped tunnels were considered and models of each proposed plan were constructed and tested before the most satisfactory design could be determined. These model tests have disclosed many conditions of flow that could not otherwise have been foreseen or provided for, and have shown conclusively that present analytical hydraulic design methods are not adequate or sufficiently developed to be depended upon solely for the economic design of such unprecedented structures. Designs which would provide safe and satisfactory flow conditions could not have been developed without model tests, which have furthermore resulted in large savings in the cost of the spillway structures. (Figs. 7, 8, 9.)

A comprehensive series of tests was made to determine the erosive effect of high velocities of water on the concrete surfaces of the spillway tunnels. Concrete blocks with various surface characteristics were cast and subjected to the continuous action of a stream of water issuing from a one-inch nozzle at velocities ranging from 100 to 175 feet per second, and inclined at various angles to the surfaces under test. These tests were continued under fixed conditions and on individual blocks for periods of as much as 34 days, and the results demonstrated the feasibility of constructing concrete surfaces capable of satisfactorily resisting erosion due to flow of water under the required velocities but emphasized the importance in this connection of good alignment and smooth surfaces. The flow of water under high velocities over the concrete surfaces of the spillway tunnels will be intermittent, and seldom, if ever, continued over more than a few days in any year.

The outlet works for Hoover Dam, which will control the flow of water to the hydraulic turbines of the power plant and to the outlet valves, will include four vertical intake towers, each about 390 feet high and 82 feet in diameter at the base. Each tower will be provided with two sets of openings served by steel cylinder gates 32 feet

in diameter, which will control the flow of water into the outlet conduits. One of these sets of openings will be at the base of each tower and one at about mid-height.

A model of these intake towers to a scale of 1:64 was constructed and tested to investigate the hydraulic flow conditions and to determine the shape and proportions of the openings to minimize losses of head. These tests led to important improvements in the hydraulic design and also established the fact that an extensive air vent system which had been included as a feature of the design was unnecessary, thus effecting a large saving in cost.

The outlet pipes and penstocks will be of welded plate-steel construction of unprecedented size, arranged in four similar systems and installed in tunnels in the canyon walls on each side of the dam. Each system will consist of a main header, 30 feet in diameter, leading from the base of its intake tower and branching to four 13-foot diameter penstocks serving the hydraulic turbines. Downstream from the penstock branches the headers will be reduced to 25 feet in diameter and each of these headers will again branch to six conduits serving the outlet valves. The maximum discharge of each of the four systems will be about 33,500 second-feet which will require a velocity of flow in the 30-foot headers of about 47.5 feet per second. Under the most severe conditions as to water-hammer, the conduits will operate under internal water pressures of about 300 pounds per square inch. To determine the pressure rise due to water-hammer under the given conditions required extensive original research and the development of formulae from the fundamentals of the mathematics involved.

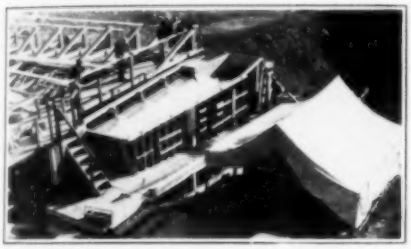


FIG. 7. MODEL OF ONE OF THE TWO SPILLWAYS OF THE HOOVER DAM, ONE TWENTIETH ACTUAL SIZE. FLOW CORRESPONDING TO 120,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

FIG. 8. FLOW IN MODEL OF HOOVER DAM SPILLWAY CORRESPONDING TO 120,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

A model of one of the systems was made, including model of the gate tower, and the hydraulic losses and flow conditions were ascertained by means of pressure measurements. These model tests indicated somewhat smaller head losses than were calculated from the tests made by Dr.-Ing. Professor D. Thoma at the Hydraulic Institute of the Technischen Hochschule, München, Germany. A transparent model of one branch connection was made and tested visually for flow conditions.

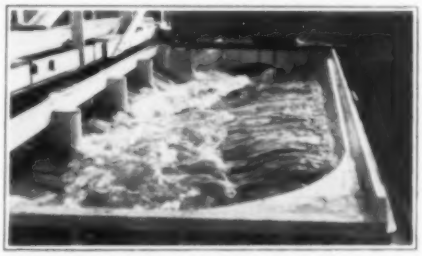


FIG. 9. THE APPEARANCE OF THE MODEL SPILLWAY FLOWING AT FULL CAPACITY, CORRESPONDING TO 200,000 CUBIC FEET PER SECOND. MONTROSE HYDRAULIC LABORATORY.

Discharges from the reservoir for uses other than electrical power development will be controlled by large balanced needle valves. On each side of the river there will be six 84-inch diameter valves discharging into the open from a valve house on the canyon wall, and six 72-inch diameter valves discharging into one of the 50-foot diameter diversion tunnels a considerable distance from its downstream end. These latter valves are arranged to discharge into the confined tunnels in order to effect a large economy in the length of the outlet pipes and also to provide a substantial part of the outlet capacity which can be operated without creating objectionable spray conditions adjacent to the power plant where many high-voltage conductors will be installed.

The correct arrangement of the six valves discharging into each tunnel is of great importance in order to avoid objectionable conditions from the standpoint of flow and erosion of concrete. This problem could only be solved by model testing. Accordingly, models were made and tested of the valve settings and tunnels to scales of 1:106 and 1:20. The arrangement of the valve discharges were varied in these model tests to determine the arrangement giving the best flow conditions. The results obtained from the two different scale models were similar and indicated satisfactory similitude between the models. These tests also demonstrated that certain provisions previously planned for introducing air into the tunnels below the valves were unnecessary and thus resulted in a material saving in construction cost.

Outlet Pipe Design: The design of the outlet pipe and penstock systems to meet the required conditions presents many unusual problems. No precedent exists for handling the quantities of water involved under such high pressures. The available space between the canyon walls is too limited to permit the passing of the pipes and penstocks directly through the dam to the outlet valves and turbines, thus requiring them to be carried in tunnels in the canyon walls. The first plan tentatively adopted was to carry the water in concrete-lined pressure tunnels, but after careful studies of the stresses that would be developed in the rock of the canyon walls and consideration of the probable results thereof, the conclusion was reached that this would not be safe construction. The mathematical studies show that zones in the rock surrounding the pressure tunnels would be subjected to high tensile stresses and that any fractures of the concrete lining and the surrounding rock would permit dangerous leakage under high pressure into the surrounding rock areas. Other studies show that it is not economically feasible to make the concrete-lined tunnels positively watertight by steel reinforcement in the concrete or by placing continuous welded-steel lining against the inner surface of the concrete lining. Either method would require more steel than the adopted plan of constructing the 30-foot diameter pipes with sufficient plate thicknesses to support the full hydrostatic pressures. This plan insures full strength and watertightness and has the further important advantage of providing space in the tunnels surrounding the pressure pipes adequate for inspection and maintenance purposes.

Many of the problems involved in the structural design, manufacture and installation of these exceptionally large pipes inside of the tunnels in this remote and difficult location are new and unusual. The problems of design are intimately related to those of manufacture and installation, and the specifications for the pipe left many of the details of design, manufacture and installation for determination by the con-

tractor, subject to the approval of the contracting officer. The contractor for furnishing and installing the pipe, The Babcock and Wilcox Company, is carrying on a comprehensive program of research, including extensive testing of small and full-scale models to destruction for the determination of stresses and the details of design. The engineers of the bureau are cooperating in this program and supplementing it with other required model tests and much analytical research. These tests and analyses are disclosing many previously unknown elements in the design of such unprecedented pipe systems, and have shown that without this research program it would have been impossible to have prepared adequate and economical designs and manufacturing processes. Estimates at this time indicate that a large saving in cost of the steel pipe will be directly creditable to the research program.

Conclusions: Nearly all features of Hoover Dam and appurtenant structures require research work to aid in securing adequate and efficient design and construction. In almost every part of the work the dimensions, forces or conditions encountered are unprecedented, and former theories and practises for work of this nature must be proven and tested as to their applicability to these unusual conditions and also supplemented with new procedures which must be developed and proven. Research, investigation and testing in many phases of design and construction are therefore necessary, and this brief outline of the work undertaken is far from complete. The results accomplished have been gratifying in the extent to which they have solved the problems which have arisen and have confirmed and supplemented previous theory and practise. The new knowledge obtained will be of great value in connection with future work of similar or greater magnitude. Thus far an estimated total saving in the construction cost of the Hoover Dam and appurtenant works of over two million dollars can be directly credited to the research program. The total cost of the program will be only a fraction of this saving, and the new knowledge developed thereby will be available without cost for use in solving similar engineering problems in the future.

RESEARCH IN THE BUREAU OF CHEMISTRY AND SOILS

By Dr. H. G. KNIGHT

CHIEF OF BUREAU, UNITED STATES DEPARTMENT OF AGRICULTURE

A PRINCIPAL object of the work of the Bureau of Chemistry and Soils is to increase the financial return to farmers by: (1) Solving certain technical problems which now stand in the way of greater or more profitable use of farm products, thereby expanding markets; (2) by more discriminating selection of soils for specific crops, the reduction of costs of fertilizers, increasing their efficiency and developing more suitable methods of application, thereby reducing unit cost of production of crops; (3) by reducing capital losses resulting from farm fires and soil erosion. These three factors concern the three fundamental elements in any industry, *i.e.*, (1) price and market for products; (2) cost of production; (3) conservation of capital.

The problems of agriculture vary from one era to another. Scientific programs of work in behalf of agriculture at the present time must take into serious consideration the present excess supply of many farm commodities and their ruinously low prices. This bureau's program has been designed to meet specifically some of the important present problems of agriculture. The work does not necessarily result in increased production. It does increase the net return to the producer and, paradoxical as it may seem, may result in reduced cost of product to the consumer.

Much of the work in this program directly assists diversification on small farms by providing greater facilities for diversification, for instance, through discovery of new uses for minor crops, thereby making possible a material degree of expansion. It also increases the profitableness of certain crops which are particularly suitable for production on small farms, for instance, by better adaptation to market preferences and by profitable utilization of surplus and wastes. Also, as a result of new methods of utilization of farm wastes and surplus, new industries are created. This not only benefits agriculture by providing a market for otherwise unutilized products, but also provides employment for labor and profitable use for capital, thus benefiting the community as a whole. Furthermore, most of such products will be used for industrial purposes. They are not so perishable as most of the staple farm food products and hence could be marketed over a longer period. This, together with the resulting increased diversification of farm products, would increase the stability of farm income.

The apple is one of the foremost commercial fruits. The United States produces more apples than any other country in the world and is the source of the largest proportion of apples entering world trade. Without the use of insecticides to control insect pests it would be impossible to produce apples on a commercial scale, and without the use of chemical washing solutions to remove arsenical spray residues it would not be possible to market apples in the United States and foreign countries where stringent regulations concerning permissible quantities of arsenical residues on apples are enforced.

The combination of salt and hydrochloric acid originated by the bureau has attained wide-spread use for the removal of lead arsenate residues from apples

SHOWING IN A SMALL WAY

IN AN EXPERIMENTAL BUILDING WHAT MAY HAPPEN ON A LARGE SCALE IN ANY DUSTY INDUSTRY PLANT THAT IS NOT PROPERLY VENTED.

and pears. The use of new fluorine compounds has been recommended to replace lead arsenate and other arsenical sprays in order to eliminate or decrease lead arsenate residues on harvested fruits.

New insecticides, such as rotenone, neonicotine and new fluorine compounds, have been developed. Tests indicate that it may not be necessary to remove residues of sprayed rotenone from apples, in which case the cost of washing apples, amounting to not less than $300,000 annually in the Wenatchee district of Washington alone, would be eliminated.

Two chemical substances have been separated from the wax-like coating of apple skins. About 500,000 pounds of each of these two substances can be recovered annually from apple pomace and peels which are now wasted in the production of cider and vinegar and in dehydration of apples. Commercial uses for these substances in lacquers, varnish removers and dry-type stencils have been found, and commercial production is being undertaken.

The development of maturity standards which have stabilized materially the fresh-fruit market have resulted in an estimated increased value for citrus fruit of at least 35 cents per box during the first five years the standards have been in force. Much sound, mature citrus fruit is unsalable because the color does not meet consumers' preferences. Development of the ethylene gas treatment for hastening the development of color, according to estimates of leaders of the Florida citrus industry, added approximately 50 cents to the market value of each box so treated during the 1930–31 season. This amounts to an increase in value of the Florida orange

FRESH EXPOSURE OF SOIL.

NEW ROAD CUTS AND DITCHES ARE ALWAYS WELCOMED BY THE SOIL SURVEY MAN AS HE CAN FROM THESE OBTAIN THE BEST POSSIBLE IDEA OF THE SURFACE SOIL, SUBSURFACE AND SUBSOIL AND UNDERLYING STRATA, AND ALSO THE COLOR, TEXTURE AND STRUCTURE OF THESE. HERE IS AN EXCELLENT EXAMPLE OF TRACING ARABLE AND PRODUCTIVE SOIL THROUGH ITS SUCCESSIVE STAGES OF FORMATION DOWN TO THE HARD ROCK FROM WHICH IT IS DERIVED.

crop of at least $4,000,000 in this one year.

The ethylene treatment for hastening coloration and reducing astringency has been extended to other fruits, such as pears, apricots and persimmons, thus increasing their value for canning or direct consumption. The citrus by-products industry of California, the most highly developed of its kind in the world, is based solely on research work by the bureau. It has to date yielded growers a total of some $7,000,000 as a result of salvaging thousands of carloads of cull and surplus lemons and oranges.

Methods of extracting lemon and orange oils and of producing an odorless pectin have been developed. Until the establishment of the citrus by-products industry in California, Italy was the chief production center for citric acid and citrates for the drug and beverage markets of the world. Our domestic industry has not only displaced most of these products from Italy, but shipments of both citric acid and citrates are being exported. Our citrates have now displaced Italy's from the leading position in the British import trade.

Canning and preserving of fruits and vegetables is the largest food industry of the United States and is represented in every state of the Union. An important problem of farmers who grow fruits and vegetables for commercial canning is the increasing competition of fresh fruits and vegetables. Extension of truck growing in the Gulf coast region, together with improved transportation and refrigeration facilities, has made certain of the most common vegetables, such as peas, string beans and tomatoes, avail-

able in fresh condition throughout the year.

The increased availability of fresh vegetables during the off season has the effect competitively of raising the standard of quality which the consumer applies to canned products. Northern canners and growers of vegetables for canning are definitely confronted with the problem of retaining more completely the original color and flavor of these products when canned. Research by the bureau has yielded an improved method of canning, which, when applied to some commodities, produces goods of superior flavor. The flavor of products such as peas and sweet corn, when packed by this method, resembles closely those of the fresh products after cooking.

The United States is the principal world source of naval stores (turpentine, rosin, pine oil, and related products derived from the pine tree) and produces about 65 per cent. of the world supply. The average domestic production for the past three years has been about 35,000,000 gallons of turpentine spirits and 2,350,000 barrels of rosin. The total value (1929 Census Report) was about $42,000,000.

An improved method of collecting pine gum to replace the wasteful and harmful practise of cutting a hole or "box" in the base of the tree has been devised. Improvements have been made in methods of distillation, still equipment and accessories used, and in the construction or "setting" of turpentine stills. Methods of testing naval stores have been outlined so as to provide suitable specifications for purchase.

The domestic sugarcane industry would profit from greater diversification of marketable products which would tend to stabilize the market and enable the industry to take fuller advantage of its contiguity to domestic consumers. A new product, "cane cream," and an improved type of "la cuite" (exceptionally thick cane sirup) have been developed. Suitable methods have been indicated for producing on the plantation special grades of molasses and brown sugars which are in demand for specific purposes by certain industries, and the sale of which would yield an increased net return per ton of cane.

The bureau has shown the possibility of utilizing the residual fiber (bagasse) of sugarcane as a raw material for rayon through the production of a satisfactory grade of cellulose. Rayon at present is almost entirely made from cotton linters and wood pulp, but the supply of cotton linters soon will not be large enough to meet the demand. Cellulose made from sugarcane bagasse is superior to wood pulp cellulose as a base for rayon.

The production of the chemical compound, phthalicanhydride, by the bureau is a discovery upon which is founded the vat-dye industry in this country. With a few exceptions vat dyes are the only dyes applicable to cotton which are very fast to light and washing. Since these dyes are applicable to cotton, the latter is being used in an ever-increasing number of applications which formerly were not developed because the cotton could not be permanently dyed, and hence did not find uses in which fastness of color was essential. This discovery has also increased the number of dyes and the variety of colors which can be applied to cotton goods, thus adding to their attractiveness. Examples of the effectiveness of these dies in stimulating use of cotton goods are women's dresses and cotton drapes.

The bureau has developed a process for producing the chemical "furfural," the industrial production of which has increased from nothing in previous years to more than 1,000,000 pounds in 1929, with consequent utilization in that year of 5,000,000 pounds of oat hulls which

CORN-COB PRODUCTS

DR. W. W. SKINNER EXHIBITS A BLOCK OF HEAT-INSULATING MATERIAL, SOME SKEINS OF RAYON DYED WITH COLORS MADE FROM LIGNIN OF THE CORN-COB, AND OTHER ARTICLES PREPARED FROM CORN-COBS, NOW ALMOST ENTIRELY A WASTE PRODUCT.

would otherwise have been useless. Furfural is used chiefly in the manufacture of resins (for production of molded articles), as a solvent, and in the purification of wood rosin.

In the production of the great staple crops—the small grains, cotton, and sugarcane—there necessarily is grown an equal and usually greater tonnage of straws, stalks and bagasse (sugarcane residue) for which on the whole there is no adequate use. Relatively small amounts are now used as roughage, bedding or as fuel (sugarcane residue) and in maintaining the fertility of the farm. A comparatively small percentage is sold for industrial uses, such as production of paper and building boards.

A comprehensive investigation of the possibilities of using these various waste materials for a great variety of purposes is being made. Attention is being directed, for instance, to the destructive distillation of these wastes and the production of various products, including activated charcoal, carbon black for painting purposes, oils and tars for waterproofing and roofing materials, fuel gas, so-called "dry ice," and numerous other products. A study is also being made of fermentation products, including fuel gas and the recovery of cellulose, fiber and other constituents, the thought here being that perhaps small towns, and even individual farm gas plants, may offer a worth-while outlet for these by-products, especially in those sections of the country where wood, coal and natural gas are not in plentiful supply locally.

The solution of these various problems of profitable utilization of agricultural wastes involves a subject of great magnitude. The stakes involved are tremendous, and a practical solution of the problem may be expected to increase farm incomes substantially.

It has been estimated that there are 1,400,000 people in the United States with diabetes or distinct diabetic tendency.

There is evidence that inulin is less objectionable in the diet of diabetics than other carbohydrates and can be eaten more freely. The Bureau of Chemistry and Soils has devised a process for producing pure inulin from chicory roots at reasonable cost. Tests of its value are now being made by six prominent medical specialists on diabetes. If present favorable indications are confirmed, use of inulin as a major source of carbohydrate in the diet of diabetics and persons with diabetic tendency would open up a large market for chicory. Chicory is at present a very minor crop, the acreage being about 3,900 acres (98 per cent. in Michigan), and the total return to farmers for the crop is about $194,000. It is at present used only as a coffee substitute. In order to supply the possible demand from persons with diabetes, a total chicory acreage of 350,000 acres would be required, and the return from this at the present price of chicory would be about $14,000,000. Work is now being done

on further reduction in the cost of inulin and on production of levulose sirup (as a by-product) of suitable quality to displace sirup made from imported cane-sugar.

Soil surveys enable the individual farmer to work out a cropping system that will permit the use of his soil resources to the best advantage. In the readjustment of cotton farming in the Southeastern states, as a result of boll weevil invasion, for example, a knowledge of the location and distribution of different soil types enabled the farmer to replace a part of cotton acreage with alfalfa. In the tobacco district such information has made it possible to select fields where the soil is capable of producing tobacco of the quality demanded by the market. In the extension of acreage of special crops in the West, soil surveys have been of great value in the avoidance of areas where the accumulation of salts and the development of alkali is a menace. In the development of reclamation projects a knowledge of soil types makes possible the avoidance of the costly mistakes which would result from carrying waters to lands not suited to agricultural development. Soil surveys are coming into ever-increasing use, as in land appraisal, the evaluation of lands in improvement of national parks, classification and allotment of Indian lands, etc. This work is being carried forward under definite plans already outlined.

Loss of soil fertility by erosion represents an annual loss which is undermining both the capital investment and the earnings of farmers throughout the whole United States. Therefore, conservation of soil resources is one of our most important agricultural problems.

More than 21,000,000 acres of land formerly under cultivation have been rendered essentially useless by gullying, and the impoverishing effects of sheet erosion are even greater. This erosive process, which occurs during every heavy rain, is gradually whittling away the productivity of 75 per cent. of the crop land of the United States. No other nation in history has ever permitted its agricultural lands to deteriorate in this manner. Many thousands of farmers are trying to make a living on erosion-pauperized land where there is little opportunity for success even when prices are good.

Improved varieties of crops, increased use of fertilizer and labor-saving machinery, and the abandonment of worn-out land for land still retaining a part of the original top-soil have contributed toward maintenance of yields. In spite of these advantageous factors and the vast amount of effort devoted to better cultivation and rotation of crops, however, the yield per acre of corn has not increased and that of cotton has markedly decreased. Good land is largely under cultivation, but acreage is being constantly reduced by unrestrained erosion. With many farmers the evil of erosion-impoverished land is not a threat of the future; it is a present handicap which makes it impossible to gain a respectable living from the soil.

Investigation is being made of the erosion processes and their control by various methods, as well as of water con-

CELLULOSE FROM SUGARCANE

D. F. J. LYNCH HAS DEVELOPED A METHOD FOR MAKING HIGH-GRADE CELLULOSE FROM BAGASSE, THE WASTE FROM SUGARCANE.

A SOURCE OF CALCIUM SALT

H. T. HERRICK, CHEMIST IN CHARGE OF FARM WASTE INVESTIGATIONS, EXAMINES THE MOLD GROWTH ON A PAN OF GLUCOSE SOLUTION. THIS MOLD IS FORMING GLUCONIC ACID, WHICH IS USED IN MAKING AN EXPENSIVE CALCIUM SALT WITH HIGHLY IMPORTANT MEDICINAL PROPERTIES.

servation. Terracing experiments are being made to determine the best and most economical type for different regions. Strip cropping is being tested on both plot and field scale basis. Strips of thick-growing, soil-saving crops, such as oats, sorghum and sweet clover, are sown along the contours of slopes, and broader strips of clean-tilled crops, such as cotton and corn, are planted between. The thick-growing crops slow down the rate of run-off and cause much of the soil carried in flowing water to be deposited along these strips.

In regions of deficient rainfall good results have been obtained by the building of level terraces and by conducting water from sloping areas out over lower-lying areas through a system of embankments that distributes the water, holds it on the land and permits it to soak into the ground for future use.

A machine has been developed which digs 10,000 holes per acre on fallow land; each excavation has a capacity of about five gallons. This scarification process, which can be done as cheaply as ordinary cultivation, holds back approximately 50,000 gallons of rain water per acre; thus absorption of water is greatly increased and erosion reduced. Investigation is being made of the rate of water run-off and the loss of soil on various slopes subjected to different cropping treatments. The relative rates of erosion of different types of fallow land, stubble land and land planted to various crops are being investigated.

While it is possible for the farmer for a brief period of time to reduce the scale of fertilizer application as an economy measure, this can be continued for only a short period before the fertility of the soil has been so reduced that profitable agriculture is no longer possible. It is the more essential that fertilizer use be continued if agriculture is to be lifted out of its present depression. It has been abundantly shown by scientific experimentation with fertilizers that through their use the cost of production can be materially reduced; in other words, that money spent for artificial fertilizers is returned with enhanced profits. This is particularly true during the present period of reduced prices for farm products. This fundamental fact is recognized by the farmer as evidenced by his continuing use of fertilizers even during the present period of economic distress. Fertilizer consumption has dropped about 50 per cent. under normal, whereas the consumption of other standard products, such as steel, has dropped 80 per cent.

The farmers of the United States normally use from seven to eight million tons of commercial fertilizer annually at a cost of approximately $250,000,000. In certain states fertilizer is the farmer's largest item of expense, as, for instance, in South Carolina, where this cost amounted to 18 per cent. of the value of all crops grown in the year 1928.

North Carolina leads with an annual consumption that did not fall below a million tons for many years preceding 1932. It is in the South and East, where conditions make it difficult to maintain soil fertility, that commercial fertilizer has assumed its greatest importance.

It is the purpose of the fertilizer researches of the Bureau of Chemistry and Soils to enhance the economies of fertilizer use through lowering their cost to the farmer, through improving their qualities, through developing improved methods of application in the field, and through adjusting fertilizers to specific soil and plant requirements.

Accomplishments in which the bureau has shared include the following: Nitrogen fixation has been established in this country and a dependable supply of nitrogenous fertilizer assured at greatly reduced cost, the savings amounting to $115,000,000 during the period 1924–1930; domestic sources of potash have been found and have already reached such a stage of development as to insure us against shortage or exorbitant prices, and savings of $89,000,000 for the last 10 years on potash costs over what would otherwise have been spent are attributed to this research program. This country has been thoroughly aroused to the advantages of more concentrated fertilizers and the average percentage of plant food has gone up year by year until the estimated annual saving on bags, handling and freight amounts to $15,000,000; a good start has been made toward correct distribution in the field.

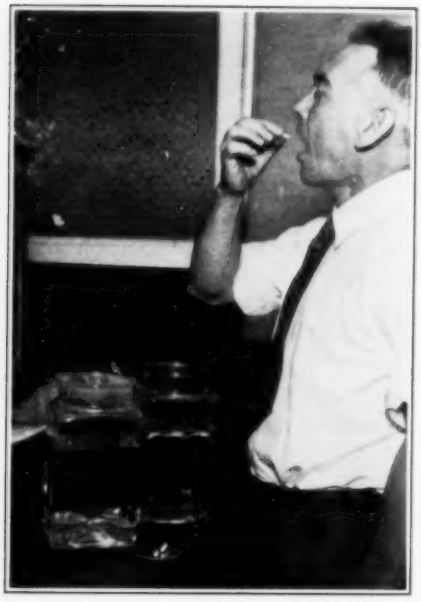
Chile can no longer dictate what we shall pay for nitrates. Nitrogen prices have dropped consistently since 1925. The saving to the farmer in the cost of the nitrogen content of his fertilizer over a 7-year period between 1924 and 1930 is about $115,000,000. In the bureau's nitrogen research program the policy has been to work out fundamentals for the use of the industry.

Another important problem is to learn how the soil bacteria accomplish so much in the way of nitrogen fixation. The quantity of nitrogen lost annually from each cultivated acre in the United States through crop removal and as a result of leaching and volatilization is on the average about 40 to 50 pounds. The soil organisms replace a considerable part of this. The problem is to find out how these organisms accomplish so much without any of the elaborate equipment so necessary to our fixation processes.

The investigations dealing with the fixation of nitrogen by bacteria are yielding two types of results: (1) They are furnishing data regarding the chemical steps involved in nitrogen fixation in nature which should later serve as a basis for cheaper nitrogen fixation methods producing organic nitrogenous fertilizers—the form in most demand by the farmer, and (2) they are yielding information of direct value to the farmer which will enable him to improve his farm practises so as to make better use of nature's fixation methods and thus

DISTILLATION APPARATUS

J. O. Reed, a chemical engineer, with the steam turpentine distiller he developed.



TESTING AN INSECTICIDE

C. M. SMITH SWALLOWS A CAPSULE OF ROTENONE, A PROMISING NEW INSECTICIDE, SHOWN BY EXTENSIVE TESTS IN THE INSECTICIDE LABORATORIES TO BE DEADLY TO INSECTS, BUT HARMLESS TO MAN.

partially eliminate the need for the purchase of commercial fertilizer nitrogen.

Potash researches were inaugurated at a time when the American farmer was wholly dependent on a foreign monopoly for all of that fertilizer essential. Importations were at the rate of 1,000,000 tons of potash salts annually and a cost of $25,000,000. The objective was the development of a domestic industry, to render America independent, to establish competition to maintain prices on a low competitive level, and to reduce costs through shortening freight hauls from producing centers to the farms where used. Great success has attended these efforts with marked savings currently accruing, which will increase as the benefits of past and present technological researches are realized.

Potash-producing units of large capacities now established in this country unfortunately are still for the most part remote from agricultural areas where the bulk of fertilizer potash is used. The 1930 freight bill of $6,500,000 on the potash salts paid by the farmer remains to be reduced through the establishment of additional production units closer to these areas and further increases in concentration of salts transportable at proportionately lower rates. Despite progress to date, payments to Europe for fertilizer potash are still being made at the rate of $12,000,000 annually. The vast deposits of potash silicates, widely distributed, are still unexploited; much by-product potash is still lost to industry. Recent technological developments, for which this bureau is responsible, show how these resources may be placed at the service of agriculture at prices reducible in terms of both production and distribution costs.

As one instance is cited the concurrent smelting of potash and phosphate rocks to produce potassium phosphate, a double fertilizer salt of 100 per cent.

POSTMEN COOPERATED WITH LEATHER CHEMISTS

MAKING STUDIES TO DETERMINE THE EFFECT OF DIFFERENT KINDS OF TANNING ON THE WEARING QUALITIES OF SOLE LEATHER.

concentration susceptible of wide distribution, and bringing into production the vast fertilizer resources of certain Rocky Mountain States with production costs that definitely promise the establishment of profitable industries, with products entering foreign competition both at home and abroad.

The United States is well supplied with phosphate rock and sulfuric acid required for superphosphate production, having long been an exporter of the rock as shown by the production and export figures.

The problems of the phosphate industry center around the conservation of the phosphate rock supply and the production of more concentrated phosphate fertilizers to cut down freight in accordance with the trend of the fertilizer industry in that direction. The present practise results in excessive waste at the mines in the form of tailings of too low grade for use in superphosphate production. Superphosphate carries only 16 to 20 per cent. plant food (P_2O_5), whereas products can be made having three times that concentration. Since superphosphate is a low-priced commodity, the cost of production being only $6 per ton under favorable circumstances, the packing and freight charges make up an unusually large part of the ultimate cost to the consumer. In many cases transportation on raw materials to the factory and on the finished product to the point of consumption amount to more than half of the cost to the consumer.

Investigations now in progress have for their objective savings comparable to those already achieved in connection with the nitrogen supply. Conservation of the phosphate rock supply will also result.

A problem of far-reaching importance in soil fertility is that of maintaining the reaction of the soil at the proper level for maximum yields and best quality of the crop. Certain of the cheapest fertilizer materials now on the market have the property of increasing the acidity of the soil. Unless means are taken to prevent this a serious decrease in the crop-producing capacity of the soils of the United States is certain to result, as has already occurred in sections of other fertilizer-consuming countries. With a view to correcting this condition a study is now being made of methods for preparing fertilizer mixtures with such a balance of acid and basic components that the reaction of the soil to which they are applied will remain the same.

Increasing the efficiency of fertilizers by determining their proper placement in the soil with respect to the seed for maximum yields has also received a great deal of attention during the past 2 or 3 years. Best results are obtained for most crops when the fertilizer is applied in bands to the side of the seed. When this is done the simultaneous distribution of the fertilizer and seed may be made in safety and the expense of their separate distribution is avoided.

HUMPHRY DAVY

THE ILLUSTRATION SHOWS THE APPEARANCE OF HUMPHRY DAVY AT THE AGE OF TWENTY-THREE, OR ABOUT TWO YEARS AFTER THE COMPLETION OF HIS EXPERIMENTS ON NITROUS OXIDE AND THE NOXIOUS GASES.

HUMPHRY DAVY AND CARBON MONOXIDE POISONING

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"A SHORT time after I began the study of chemistry, in March 1798," wrote Humphry Davy in his book on nitrous oxide,[1] "my attention was directed to the dephlogisticated nitrous gas of Priestley, by Dr. Mitchill's Theory of Contagion." In a footnote thereto appended, it was explained that the New York physician, Samuel Latham Mitchill, had suggested that nitrous oxide, which he called oxide of septon, was responsible for the plague. The gas, when inhaled, was supposed to produce sudden death, and scarcely less terrible results when applied to the skin. "The fallacy of this theory," continued Davy, "was soon demonstrated by a few coarse experiments made on small quantities of the gas procured from zinc and diluted nitrous acid. Wounds were exposed to its action, and the bodies of animals were immersed in it without injury; and I breathed it mingled in small quantities with common air, without remarkable effects. An inability to procure it in sufficient quantities, prevented me at this time from pursuing the experiments to any greater extent. I communicated an account of them to Dr. Beddoes."

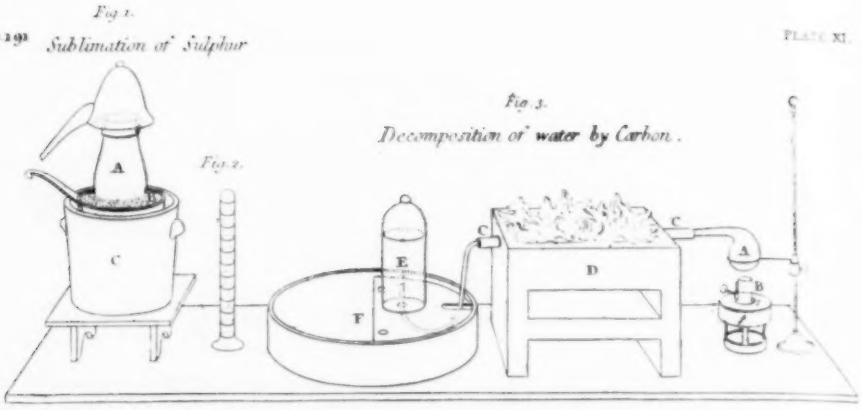
There is little doubt that these researches of the youthful poet and philosopher, together with other qualities described in detail by his biographers,[2,3] were largely instrumental in securing his first appointment. In 1798 Davy was released from an incompleted apprenticeship to Mr. Borlase, an apothecary-surgeon in his native town of Penzance, to assume the duties of laboratory director at the Medical Pneumatic Institution in Bristol. The necessary equipment was made available in the early part of 1799, from funds obtained through the efforts of Dr. Beddoes, for the study of the possible therapeutic value of various gases. Medical scientists, then as now, were eager to apply the latest discoveries in chemistry to the treatment of diseases. It was only natural that the study of the "factitious airs" should be undertaken. Carbon dioxide had been described by Black in 1757, hydrogen was isolated by Cavendish in 1766, oxygen by Priestley and Scheele in 1771, nitrogen by Rutherford in 1772 and, in the same year, nitrous oxide by Priestley. When Davy began his studies in the new laboratory at Bristol, the contributions of Lavoisier to the chemistry of respiration had been terminated by the execution of the founder of modern chemistry but five years before.

Within a comparatively short time, Davy had learned to prepare large quantities of nitrous oxide in pure form, had analyzed the gas with surprising accuracy, considering the limitations of his apparatus, and had showed its relationship to nitric oxide. The chemical

[1] The quotations herein are taken from John Davy's "The Collected Works of Sir Humphry Davy. Volume III. Researches, Chemical and Philosophical, Chiefly Concerning Nitrous Oxide, or Dephlogisticated Nitrous Air, and Its Respiration." London (1839). This monograph was first published in 1800.

[2] John Davy, "Memoirs of the Life of Sir Humphry Davy, Bart." London (1836). Two volumes.

[3] J. A. Paris, "The Life of Sir Humphry Davy," London. 1831.



THE FIGURE FROM JANE MARCET'S "CONVERSATIONS ON CHEMISTRY," AMERICAN EDITION OF 1818, EDITED BY THOMAS COOPER, SHOWS THE TYPE OF APPARATUS ONCE USED TO PREPARE SMALL QUANTITIES OF WATER GAS. MRS. MARCET'S BOOK WAS BASED ON DAVY'S LECTURES AT THE ROYAL INSTITUTION IN LONDON, AND WAS RESPONSIBLE FOR INTERESTING MICHAEL FARADAY, AS A BOOK-BINDER'S APPRENTICE, IN THE SUBJECT OF CHEMISTRY.

aspect of the problem thus being placed on a firm basis, he turned his attention to the detailed study of the effects produced by breathing nitrous oxide. In the early experiments animals were used. They included dogs, cats, rabbits, guinea-pigs, mice, a hen, a goldfinch, "water lizards," two species of fish, butterflies, a drone, flies, snails and worms. The land animals were placed in atmospheres of nitrous oxide, the fish were immersed in water that had been saturated with the gas, and the "water lizards" were tried in both. Though the experiments on the animals yielded some interesting data, they were not considered satisfactory because, as Davy remarked, the animals all succumbed in about the same time in nitrous oxide as in those gases known to be incapable of supporting life. It was thereupon decided to make observations on himself. For present purposes we need not dwell upon the experiments on "laughing gas," as Davy's nitrous oxide came to be known, because they immediately attracted popular attention and because they are still counted among the commonly known anecdotes of the history of chemistry. In passing over these familiar experiments, however, let us not forget the zeal with which Davy pursued his studies. We may carry with us, if we like, a mental picture of the young investigator on the day after Christmas in 1799, crouching in an air-filled box for an hour and fifteen minutes, feeling his pulse and recording his body temperature with a large bent thermometer placed under his arm, while assistants admitted more and more nitrous oxide into the chamber.

But among the less well-known investigations described in Davy's monograph are several of historical significance as early contributions to the study of respiration and the toxicology of the noxious gases. These experiments were performed by Davy on himself to compare the effects produced by nitrous oxide with those evoked by other gases. Nitrogen, hydrogen, carbon dioxide, nitric oxide and water gas were studied.

When breathed in small quantities, nitrogen and hydrogen produced only symptoms of suffocation; they were said to be inert because they did not produce the subjective excitement typical of partial anesthesia. Different results were

obtained with carbon dioxide. "It tasted strongly acid in the mouth and fauces," Davy said of the pure gas, "and produced a sense of burning at the top of the uvula. In vain I made powerful voluntary efforts to draw it into the windpipe; at the moment that the epiglottis was raised a little, a painful stimulation was induced, so as to close it spasmodically on the glottis; and thus in repeated trials I was prevented from taking a single particle of carbonic acid into my lungs." The same protective mechanism was set in action by air containing 60 per cent. carbon dioxide. When the concentration was reduced to 30 per cent., the mixture was respirable for short intervals. No marked effects were observed other than those due to deprivation of oxygen, unless the symptom of sleepiness that was also recorded is interpreted to mean the effects of the hyperpnea which is now known to be produced by carbon dioxide.

In a "fit of enthusiasm," an expression with which the modern reader will probably agree, Davy tried to breathe nitric oxide. This gas combines with the oxygen of moist air to form brown fumes of nitrogen dioxide and, to avoid this reaction, Davy breathed the gas after preliminary inhalation of nitrous oxide had removed most of the common air from his respiratory tract. The toxicity of the higher oxides of nitrogen is now known to be due to their action on the lungs. They dissolve in the cellular fluids of the lung tissue, forming acids and producing irritation and the slow accumulation of more or less fluid. In a severe case of poisoning the victim may die from edema of the lungs some hours after the immediate effects of the gas have worn off and the patient feels that he has recovered. Fortunately, as Davy realized when the experiment was abandoned, it was found impossible to draw the gas beyond the glottis. The fumes burned the mouth of the young experimenter and made his teeth sensitive.

Although Davy was saved considerable discomfort, if not more serious consequences, from the acid-forming gases by the spasmodic closure of the glottis, this protective reflex was not elicited by another toxic gas that he studied. This was "hydrocarbonate." It is now known as water gas, because it is made by boiling water and passing the steam over heated charcoal. Although the main reaction can be written $H_2O + C = H_2 + CO$, showing that equal volumes of hydrogen and carbon monoxide are formed, small amounts of carbon dioxide and hydrocarbons are also produced, traces of oxygen and nitrogen are present, and the carbon monoxide content is usually not more than 40 per cent. The toxic properties are due to the carbon monoxide, although there is some evidence that commercial illuminating gases, such as coal gas, are somewhat more poisonous than their content of carbon monoxide would indicate. It was not until 1857 that it was proved, by Claude Bernard, that carbon monoxide is not a simple asphyxiant, but acts by forming a firm combination with the hemoglobin of the blood, and thus deprives the tissues of oxygen. Nevertheless, Davy stated that hydrocarbonate destroyed life "by producing some positive change in the blood, which probably immediately renders it incapable of supplying the nervous and muscular fibers with principles essential to sensibility and irritability." One need only explain that the essential principle is oxygen and, perhaps, add a few details concerning the decreased rate of transfer of oxygen from blood to tissues in carbon monoxide poisoning, and the statement is brought up to date.[4] As is

[4] A recent account of the anoxia of carbon monoxide poisoning is presented in the treatise of J. P. Peters and D. D. Van Slyke, "Quantitative Clinical Chemistry. Volume I. Interpretations." Williams and Wilkins Co., Baltimore. 1931.

indicated in the following account of his experiments, Davy was not the first to work with water gas inhalation, and the prophetic conclusion cited above was partly based on earlier contributions.

Mr. Watt's observations on the respiration of diluted hydrocarbonate by man, and Dr. Beddoes's experiments on the destruction of animals by pure hydrocarbonate, proved that its effects were highly deleterious.

As it destroyed life apparently by rendering the muscular fibre inirritable without producing any previous excitement, I was anxious to compare its sensible effects with those of nitrous oxide, which at this time I believed to destroy life by producing the highest possible excitement, ending in lesion of organization.

In the first experiment, I breathed for near a minute three quarts of hydrocarbonate mingled with nearly two quarts of atmospheric air. It produced a slight giddiness and pain in the head, and a momentary loss of voluntary power: my pulse was rendered much quicker and feebler. These effects, however, went off in five minutes, and I had no return of giddiness.

Emboldened by this trial, in which the feelings were not unlike those I experienced in the first experiments on nitrous oxide, I resolved to breathe pure hydrocarbonate.

For this purpose, I introduced into a silk bag four quarts of gas nearly pure, which was carefully produced from the decomposition of water by charcoal an hour before, and which had a very strong and disagreeable smell.

My friend, Mr. James Tobin, Jun. being present, after a forced exhaustion of my lungs, the nose being accurately closed, I made three inspirations and expirations of the hydrocarbonate. The first inspiration produced a sort of numbness and loss of feeling in the chest and about the pectoral muscles. After the second inspiration, I lost all power of perceiving external things, and had no distinct sensation except of a terrible oppression on the chest. During the third expiration, this feeling disappeared, I seemed sinking into annihilation, and had just power enough to drop the mouth-piece from my unclosed lips. A short interval must have passed during which I respired common air, before the objects around me were distinguishable. On recollecting myself I faintly articulated, "*I do not think I shall die.*" Putting my finger on the wrist, I found my pulse thread-like and beating with excessive quickness.

Davy's description of the symptoms of carbon monoxide poisoning is strikingly similar to the more precise account by Haldane in 1895. By means of a rapid method for the quantitative estimation of the amount of the blood pigment combined with carbon monoxide, this distinguished English physiologist was able to correlate the symptoms with the degree of saturation of the blood. When one third of his blood pigment was combined with carbon monoxide, Haldane noted symptoms of discomfort when quietly resting, and complained of dizziness, palpitation and blurring of vision when the oxygen deficiency was accentuated by exercising. With the blood half saturated, even the resting subject was on the verge of collapse. From Davy's description it would appear that his blood was about half saturated with the gas. It may also be noted, in resuming the account, that the symptoms of asphyxiation became aggravated following exertion.

In less than a minute, I was able to walk, and the painful oppression on the chest directed me to the open air.

After making a few steps which carried me to the garden, my head became giddy, my knees trembled, and I had just sufficient voluntary power to throw myself on the grass. Here the painful feelings of the chest increased with such violence as to threaten suffocation. At this moment, I asked for some nitrous oxide. Mr. Dwyer brought me a mixture of oxygen and nitrous oxide. I breathed this for a minute, and *believed* myself relieved. In five minutes, the painful feelings began gradually appeared, and I felt only excessive weakness to diminish. In an hour they had nearly dis- and a slight swimming of the head. My voice was very feeble and indistinct. This was at two o'clock in the afternoon.

I afterwards walked slowly for about half an hour, with Mr. Tobin, Jun. and on my return, was so much stronger and better, as to believe that the effects of the gas had disappeared, though my pulse was 120, and very feeble. I continued without pain for near three quarters of an hour, when the giddiness returned with such violence as to oblige me to lie on the bed; it was accompanied with nausea, loss of memory, and deficient sensation. In about an hour and a half, the giddiness went off, and was succeeded by an excruciating pain in the forehead and between the eyes, with transient pains in the chest and extremities.

Toward night these affections gradually diminished. At ten, no disagreeable feeling except weakness remained. I slept sound, and awoke in the morning very feeble and very hungry. No recurrence of the symptoms took place, and I had nearly recovered my strength by the evening.

Since Davy's time it has been shown that carbon monoxide is a cumulative poison, its effects being dependent not only on the concentration in the inspired air, but also on the time of exposure and the rate of respiration. Henderson and Haggard[5] have estimated that three parts of carbon monoxide in ten thousand is the maximum permissible in atmospheres to which men may be exposed for several hours. The gas is eliminated from the body in the form of the unchanged monoxide, and through the same channel as it enters, the lungs. Haldane found that the breathing of oxygen gas alleviated the symptoms of poisoning, but even after being able to move about normally, a violent headache, such as Davy described, persisted. This symptom is supposed to be caused by pressure in the brain that results from the edematous swelling that, in turn, is brought about by the anoxemia. The modern method of resuscitation was devised by Henderson and Haggard. It consists in the administration of oxygen containing 5 per cent. carbon dioxide. The latter gas is the natural stimulant for respiration, its inclusion causing deeper breathing and bringing about the elimination of carbon monoxide in a much shorter time than is possible with oxygen alone. In the majority of subjects treated by this method of resuscitation, which is very effective provided it is begun before the heart has actually stopped beating, no after-effects are experienced. Even the severe frontal headache is often prevented.

To those familiar with the development of our knowledge of the toxic gases since 1800, when Davy's monograph first appeared, it is well known that much information has been derived through the medium of animal experimentation. Such knowledge has been supplemented from time to time by observations made on scientific men themselves or on the unfortunate victims of gas poisoning. A number of investigators have been injured or killed in the course of laboratory studies on respiration. Fortunately for the history of chemistry, Davy did not become a martyr to science and, as his brother has recorded, condemned the practice of self-experimentation in a letter to a medical student a few years after his almost disastrous experiences with the toxic gases.

[5] Yandell Henderson and H. W. Haggard, "Noxious Gases and the Principles of Respiration Influencing Their Action." Chemical Catalog Company, New York. 1927.

PLAYING THE SCIENTIFIC GAME

By Dr. MAURICE C. HALL

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A DICTIONARY definition of science is to the effect that science is classified knowledge, or is knowledge gained and verified by exact observation and correct thinking, or is an exact and systematic statement of knowledge concerning some subject. The term scientist is defined as one versed in science or devoted to science. Actually, although the word science implies knowledge, the term is commonly used to mean research, and a more adequate definition of science would take cognizance of the business of acquiring new knowledge. The dictionary definition is, in effect, a teacher's definition of science as it is presented to undergraduate students. It does not express the meaning which investigators commonly attach to the word science, and in emphasizing our knowledge such definitions contribute to our delinquency in allowing students to escape from science courses without grasping one of the most important things science can teach us, which is the meagerness of our knowledge and the appalling extent of our ignorance. The meaning definitely attached to the word scientist by scientists is that of investigator. A teacher of science may or may not be a scientist, in the sense in which scientists use the word, just as a writer of detective stories may or may not be, and usually is not, a detective.

Whatever our definition of science, our actual concept of it is colored and flavored by our experience and temperament, and attempts to convey our concept to persons who have never hunted elusive facts and unknown things is usually not very successful. Some scientists regard research as an occupation which occupies their working hours. Some regard it as something akin to a religious activity. Personally and at this time I prefer to regard it as a game which has a peculiar charm. Games are affairs of competition or of chance, and science is both a competitive match and a gamble. The scientist's generally recognized opponent is nature, and this dear antagonist numbers among her many charms that most precious of good qualities in gamesters—sportsmanship. For nature has shown in all her dealings with her human opponents that she plays the game fairly. The scientist has another opponent, the believer in magic, and this dark opponent, who is not so generally recognized, plays a more devious game.

Nature's habit of fair play commands the scientist's respect and admiration. The scientist undertakes to trick nature out of her secrets, to pry into her mysteries and to learn her laws, in order that when he has discovered those secrets, mysteries and laws, he may harness the forces of nature, render her deadly weapons harmless, and change her from a dread goddess to his slave. Mortal antagonists approached in such spirit and with such intent show little regard for such rules of the game as may be drawn up, or for fair play, but nature is quite sporting about it.

Our delightful opponent has arranged the game along these lines: We can come constantly closer in our approach to absolute knowledge, to ultimate things and to perfection, but we can attain none of these things. Nature agrees to observe the laws of cause and effect, operating in due sequence and with re-

sults proportional to cause. She will do nothing to stop our investigations except as we run afoul of her laws of cause and effect, and will wage on us no counter-war except as she has already laid on us her inhibitions by building into her human creation those things which constitute the nature of man. Because of those inhibitions, manifest in what is called "human nature," our other opponent, the belief in magic, is invoked against us and we become our own worst enemies.

The impossibility of our attaining perfection is one of the earmarks of nature's arrangement that stamps it as a perfect arrangement. It would be disconcerting to find that nature had set up this fine large universe in such shallow fashion that the inconsequential human animal, with his all too evident imperfections, could grasp some part of that universe in its entirety, and present to critical intellects the appalling spectacle of imperfection comprehending perfection. It would be a gloomy outlook if there were the likelihood that we might know everything, and thereby court eternal boredom. Finally, if the scientist could know everything about his subject, he would work himself out of a job, and ultimately have to turn to politics, law or writing, where the inexhaustible supply of words promises to furnish endless occupation unless humanity finally talks or reads itself to death. Fortunately, there is no threatened answer to Faust's question:

"Welch Schauspiel! Aber, ach! Ein Schauspiel nur!
Wo fass' ich dich, unendliche Natur?"

The dependability of nature's law of cause and effect makes science a real game of skill, as well as chance. It permits us to repeat our experiments with the certainty that nature, unlike human law-makers, will not pass new laws overnight, and that an acid will not turn litmus pink one day and blue the next day. The principle of uncertainty has not upset our confidence that nature will play the game fairly and according to rules which we can formulate and on which we can depend. Nature does not play politics, she does not vote dry and drink wet, and she registers her vote on all subjects without diffidence, modesty or hypocrisy.

While nature will play the game fairly and dispassionately, she has from ancient times set up her defenses against the prying eyes and poking fingers of the scientist. One of her defenses is inherent in the intricate mechanism of the universe. The qualities of infinite vastness and infinite minuteness, of infinite variety in shape, color, sound and odor, of infinite varieties in speed, of endless reactions and interactions, and other complexities, ensure that nature will ultimately outwit finite minds.

But even more efficient is the opponent which nature has evolved in molding the mind of the man who seeks to solve her cryptic composition. In his long ascent to his present not too high station as an intelligent animal, man has constantly been under the lash of nature, and by many centuries of attack with famine and disease, with fang and claw, with volcano and earthquake, she has built into his soul fear and furtiveness and dishonesty. For thousands of years man has sought to placate the destroyer, and it is from a stuff into which a cringing soul is built that the mind of to-day's scientist must be shaped. This odd little product of nature, man, has for thousands of years looked with terror at his creator, and although he now looks at her with questions in his eyes, nature can look with smiling confidence into those questioning eyes. She has in good time taken steps to blunt the weapon which man now turns against her. For that weapon of research is the mind of the scientist, and that weapon she has

herself fashioned, as Excalibur was fashioned, with specific powers and quite adequate limitations. Who wields this weapon effectively must have the qualities of keenness, courage and honesty, and this requirement is a restraint which is put upon us. Keenness without courage, courage without honesty or honesty without keenness will not serve. Stupidity, cowardice and dishonesty alike are fatal to the scientist, for none of these serve Truth, and all of them serve the believers in magic.

A certain keenness is not lacking in man's mental make-up. Dodging saber-toothed tigers, stalking game, snaring fish, climbing trees and mountains, devising home and clothing from such parts of the scenery as lent themselves to such uses, and otherwise solving the urgent problems of self-defense and food could not fail to put an edge of some sort on the mind of man. The experimental method of trial and error had its beginning among ancient things, and the scientist needed only a somewhat new set of problems and some refinements in procedure to start him on his new career; keenness of intellect in some degree might be predicated of him with some assurance.

Of moral courage not quite so much could be expected. Our minds are still dominated by fear, fear of pain and hurt, fear of losing our living, fear of losing our reputation, fear of trouble and struggle. There is in science some antidote for fear, since science is the search for reality, and fears are mostly imagination, but the scientist remains human, and because he is human, he, too, courts unreality and delusion, and desires ease and comfort and certainty and approval and applause, and fears the loss of these things. There is in science a discipline that is to some extent a stiffener of courage, for many of our experiments show the poverty of our reasoning and bring to us a disappointment that must either temper our courage or unfailingly breed discouragement. There is in science little of reward in material things, and courage may be expected to spring in minds which renounce the soft life. But science works no miracles in tempering metals that can not withstand the tempering fire.

As regards the quality of honesty, in the sense of intellectual honesty, one may expect substantially as little as of moral courage. For thousands of years man had lived by his wits. He had outwitted huge reptiles and mammals, but the result was a development of shrewdness rather than a balanced intelligence. There is a quality of trickiness about cleverness in combat and war. It breeds deceit and dishonesty rather than straight thinking.

And when man's tricks and deceits failed, he suspected nature of animistically taking sides in his affairs, and sought to appease and bribe her. Later he called upon his various gods to help him and to defeat his opponents. From such pious beginnings man has developed his second enemy, the belief in magic. For the essence of science is that nature's laws are observed, not part of the time or most of the time, but all the time, whereas the essence of magic is that nature's laws, like man's laws, are capable of being evaded, modified, suspended or vetoed. Mankind desires, and seems to expect, as a solution of most of its problems, something along the lines of a Gilbert and Sullivan opera. Somewhere, perhaps just around the corner of which we have heard so much, is a Little Buttercup waiting to admit that she "mixed them babies up," after which all will be well with "this best of all possible worlds." It is with genuine regret that we dismiss the expectation of the Gilbertian solution and of the delightful magic effects with which Cabell fulfils the desires of his heroes and heroines, for these things have the

merit and charm of artistry. However, it is only in such fields as law that the Gilbertian interpretations are taken seriously, and the Cabellian formula achieves highly impermanent results for its heroes and heroines. The only permanence achieved is that inherent in Gilbert's and Cabell's artistry. The scientist not only expects that science will have as much permanence as art, but that scientific thought and its benefits to mankind will last at least as long as that fragile and vulnerable race. Somewhat like Père Coignard, we may believe that such personal matters as religion and romance and art can be dealt with in a spirit of faith and emotion, but that communal affairs must ultimately be dealt with in a spirit of common sense and intelligence and facts.

It is not just the man on the street, the farmer in the dell and the savage in his jungle, who believe in magic. In one way or another, scientists in general believe in some fashion what they disbelieve in another fashion, that nature does not always play the game fairly and that she can be persuaded by appropriate supplications, incantations or ceremonies to suspend her laws of cause and effect, to skip the beats in her accustomed rhythm, to double-cross some one or something and to dispense special favors to the initiate and elect. Whether our belief in magic takes the form of a belief that the hex spell may be cast on an enemy, or disaster ensured by the lighting of three cigarettes with one match, or rheumatism cured by carrying a buckeye in our pocket, or economic troubles cleared away by voting the right ticket or sociologic problems solved by the passage of a law, is only the difference between black, white or gray magic. One way or another nature has set her limitations on our intellectual honesty, and there is no lack of scientists who make their data prove the conclusions they set out to prove or destroy the specimen that does not fit into their classification. Intellectual honesty is difficult to achieve; one is tempted to say of man at this stage of his development that it is almost impossible to achieve. We have developed methods for our combat with nature. By what methods are we to combat magic? What are we to oppose to the abracadabras, exorcisms or cantraps of the magician?

Man does not enter the field of science as a scientist. He enters as a man and a novice, and many who work daily in laboratories and are called scientists never conclude the novitiate which endows them with the scientific mind, or, if they have achieved it, never take that mind out of the laboratory. We bring with us our established patterns of childish behavior and the sense of values inculcated in childhood. We have been told, and we have believed, that gold is good, that fame is admirable, and that assurance of ease is a worthy end in life. It is hard to unlearn these lessons, to pursue truth instead of profit, to look for facts instead of fame, to scan our specimens and our reactions and not the lists of degrees, awards and prizes, and to elect the life of work and reject the life of ease. Science dispels illusions, and it takes courage to withstand disillusion and still face smilingly and with a high heart a life of reality which eludes us and a certain death which overtakes us. Courage is not granted to all men, be they scientists or not, and the hobo and idle inheritor of wealth do not walk the path of social parasitism unaccompanied by what are called and generally believed to be scientists.

There is no magic in research. Scientific facts can be taught, and are taught. Research methods can be taught and would be taught better if we could disabuse our minds of the idea that there is some magic by virtue of which this man is a research worker and that man is not. It is not magic that makes the

investigator; it is the possession of intellectual keenness, courage and honesty, a capacity for applying these qualities to our work and to our life, and the ability to strengthen these qualities by constantly exercising them. On any basis of fact content of any sort, and in dealing with any subject-matter, the systematic application of these qualities in a search for new facts is research.

You will not think that I come here to criticize science or scientists before my "companions in zealous research." If this is no eulogy of science as it is manifested to our observation, it is at least an appreciation of what might be, and to some extent is, a search for truth, and is an appraisal of the difficulties and hazards of playing the scientific game. If it is no eulogy of all scientists or scientists in general, it is a recognition of the stuff that the players must have, and sometimes do have, to play the scientific game. In a world of relativity I rate the scientist high by virtue of his ideals and his strivings and his achievements as compared with those of others.

Our great opponent, nature, is vast in resource and subtle in method. We play what I fear is a losing game, where we can count on gains but not on victory. Our game must be played for the joy of the game and not for the sake of winning. For in the end nature will overcome us. She will inevitably defeat us as individuals, preserving an occasional rare specimen in her splendid paleontological collection, and returning the rest of us to her laboratory to be reworked into new experiments in plant and animal life or stored among her chemicals.

For nature is the great scientist and the great experimenter, who plays her scientific game on a vast scale, with man as one of her experiments. In all probability she will some day dispose of the human race in some such way as she disposes of us as individuals. When she closes her books on this experiment, in which we are the guinea-pigs, we hope that in writing up her conclusions she will at least make passing reference to "this interesting experiment." That hope, at least, feeds our vanity and sustains that sense of importance which is so essential to human happiness. Meanwhile the scientist, who must suspend judgment on inconclusive evidence, may hope that we are important, but he will hold *sub judice* the question: Are we an important experiment or a minor experiment? For that matter, can any one say in science that one fact is more important or less important than another? It is a far cry from the simple experiments of Volta and Galvani to our modern electrical marvels, but were the parental voltaic pile and the observations on frog's legs swinging on hooks less important than are their children of radio, television and x-rays?

It may be asked whether there is any reason why a young man confronted with such ideas as are here expressed should elect to play this scientific game. And what may be answered: "Yes, if he has the qualities necessary to play it well." But what are the rewards? The rewards are mostly those arising from the difficulties. They are the rewards that come from playing intellectual games in which skill, courage and honesty are necessary, because these qualities develop by exercise, and the achievement of a greater intellectual keenness, courage and honesty is a high reward.

I have already said that the material rewards are not great. I would go further and say that there is a certain incompatibility between the service of science and the service of the god called Mammon. Among the poems, philosophical writings, history and other things which make up the Bible, there is a statement which seems to embody a sound economic and sociologic doctrine: "The love of money is the root of all

evil." The scientist can not dispense with money in his personal life or his scientific work, but the love of money and the desire for wealth are something else. In a wide acquaintance with scientists it has seemed to me only too evident that the scientist who conspicuously divides his energies between his work and his investments diminishes his value as a scientist proportionally. It still seems true of our intellectual and moral energy, as of other things, that "the more you dilute it the thinner it gets."

It may be said further that fame is a poor reward on which to focus the attention of the student who is considering the life of a scientist. We must take our work seriously, but only the scientist who takes himself seriously, which taking is itself a grave social sin, will greatly esteem his personal contribution to science. In laying upon us the limitations as to what may be achieved by adventures with the imperfect human brain and eyes and ears and nose and tactile sense, nature has fixed the status of the scientist in this fashion: He may achieve no final thing, but it is his rôle to maintain the continuity of scientific thought from the past through the present in order that the science of the future may move on more rapidly because of his work. As older players die, younger men step into their places, face the ancient opponent, struggle to advance the ball an inch or a yard, and give place to new players. There is no touchdown in sight, but for whatever reason may animate us, we play this game with a determination that no ground shall be lost to our great adversary by us. But not for fame, not for office and title and high headlines. For the love of the game and, in lieu of fame, for the regard and friendship of our scientific confrères who can best judge our work, and who, conscious of whatever of innumerable human weaknesses may be ours, still find our data valid and our conclusions sound. Scientific verity and fame may be contrasted in the words Coth said to Dom Manuel: "But, master, we are men of this world, a world made of dirt. We pick our way about that dirt as best we can. The results need surprise nobody. The results are rather often, in a pathetic fashion, very admirable. Should this truth be disregarded for a vainglorious dream?"

I have said that the scientific game is not only a game of skill, but a gamble. As a gamble it has the appeal of magnificence. Many men gamble to put money in their pockets. The scientist gambles to add new and splendid stars to our galaxies, he gambles to enlarge the mental horizon of mankind, and he gambles to put millions of dollars in the pockets of other men. In spectacular fashion he has made possible our modern transportation and communication systems, and has left the profit and the glory of it all to the business man. He has restored the sick and healed the wounded. He has made, not two, but many, blades of grass grow where one grew before, and made better grasses. He has increased economic production in manifold fashion, and in no small way has brought upon the world the economic disaster that now overwhelms it.

For in this game with nature, the scientist has advanced our football of knowledge without regard to what humanity was doing as it followed him over the ground he had won. And what humanity has done has not always been in that spirit of splendid devotion to truth, courage and honesty which the scientist has sought to achieve and in some measure has achieved. It gives us pause to reflect on what we have done and on what has come from those achievements which looked so magnificent and seemed to hold such promise of good.

Perhaps there has been too much

singleness of purpose on our part. Perhaps we should have devoted less time to science and more to citizenship. For quite apart from all controversy of pure science and applied science, it is the thought of scientists that our work achieves either intellectual or material benefit to humanity. One may find here and there the scientist who professes no concern with humanity, but only with abstract truth. Such scientists stand on a somewhat shaky pedestal, for the downfall of civilization and of humanity must be the destruction of science. If the elaborate structure on which science now rests should fall, a scramble for edible roots and berries may be confidently expected to occupy our energies to the exclusion of the search for abstract truth.

As scientists, however, we may doubt whether the mathematician should devote less time to calculus and more to citizenship, whether the veterinarian who is gambling a few hundred dollars and the lives of a dozen cows to save millions of dollars and thousands of cows for other men, should curtail this practical work in economics to study tariff bills. It would seem better that our fellow citizens play their games of politics, economics and sociology in the scientific spirit. The basic intellectual essential of the business man for thousands of years has been the elementary ability to buy for one dollar and sell for two dollars, but even with such meager minimum intellectual essentials, industry has learned to employ the scientist to do its research and to point out the application of that research. To be sure, industry, by and large, has paid trivially for scientific brains, but industry has at least learned to use them.

It is now high time that in politics we began to play the scientific game and to consult the economist, sociologist and psychologist who have specialized knowledge of the raw materials from which society and its activities are made. I realize that not all scientists will agree with this thought, but it seems to me that my dissenting colleagues are either defeatists who expect man to fail to solve his social problems, or are paying homage to the magicians when they expect those problems to be solved by our current stock of politicos and magnificos. In the hurricane of economic disaster now blowing around our planet, one seeks in vain among the organizations of our non-scientific great ones for some weather bureau that has charted the origin and course of this storm and can predict its duration and possible termination. Our great minds prescribe a dose of confidence or headache powders, or pass laws ordering a restoration of prosperity, or even suggest the madness of a greater storm in the form of war as a cure for our ailments. Some of the great medicine men are advocating a good dictator, but as a zoologist I note that nature preserves species and wastes individuals, I note that dictators, good or bad, share our mortal impermanence. I see that referring the problems of nations and centuries to individuals who die is only a motion to postpone, and I look askance at all such simple solutions of governmental problems as savoring of the usual moronic demand for a magician.

And so I turn to scientists for a solution. As scientists we must stand on the platform of *Nil sine numine*. Behind this phenomenon is its noumenon, and for these visible effects there are proportionate causes. These relationships are discoverable to scientific inquiry, and the time to learn them is ripe, if not over-ripe. If scientists can not solve our problems, we must accept defeat, but we shall only waste time by awaiting the miracles of the magician.

It is preposterous to assume that, if a savage can comprehend his simple culture, a civilized man can not compre-

hend a more complex culture if there is as much rationality in it as there is in that of the savage. If civilization is not rational, it must be shaped to a rational pattern. We can not concede that the race which produces men who tear atoms to pieces and follow the course of remote comets can not produce men capable of organizing and managing those affairs by which we might all be comfortably fed, clothed and housed. If man's morals, ethics, emotions, habits, customs and needs constitute a baffling mixture, so, too, do the composition of proteins, the functions of the brain, the structure of chlorophyl and the innumerable radiations in physics, yet we make progress with these latter things, and probably shall with the former. If the overlords of society have failed, it is not because they have used the scientific method. As scientists we may still believe that the solution of social problems will follow from the application of the scientific method in sociology as in the physical and biological sciences. For that matter, sociology and economics are biological sciences, for *Homo sapiens* is an animal, whatever else he may be or hope to be.

In government, which, after all, is only the collective business of social groups, we must adopt the scientific spirit. We must demand of the politician, as we do of the scientist, that he bring to his job an adequate fact content of knowledge and an increasingly large measure of intellectual keenness, courage and honesty. We must discourage the childish view that fame and fortune are of themselves admirable and desirable things. We must combat our belief in magic. There is no easy way to scientific achievement or worth-while achievement of any sort. There is only the way of intelligent effort, and intelligent effort implies that the mind and our physical force must be exercised. Magic always implies the easy way of the wishing ring, the magic carpet or Aladdin's lamp, wish fulfilment by the simple process of wishing. This is still the method of politics. Only a very naïve mind can believe that majority votes can select ability, courage and honesty offered on a propaganda basis.

To qualify as a candidate for junior scientist, competent to play the scientific game in the government service at $2,000 a year, a salary now likely to be marked down in order to help unemployment and restore prosperity, the law provides that a man must be a graduate of a recognized college, must pass an examination in his subject-matter, and must present an acceptable thesis. To qualify as a candidate for the presidency of the United States at a salary of $75,000 a year, the constitution provides that a man must be 35 years old, a natural born citizen and have lived in this country for 14 years. With all due respect to the high occupation and standing of the scientist, one can hardly escape the conclusion that our requirements for a president are not sufficiently exacting, and experience indicates that not all presidents have had much beyond these minimum constitutional qualifications. Surely the qualifications for the head of this great government should be somewhat higher, more detailed and rigid. If the scientist must have education, training and experience qualifying him for his job, if he must have intellectual keenness, courage and honesty for his individual combat with nature, something of the sort must be demanded of the politician who is to conduct our collective combat with nature, magic, and our social parasites and predators.

Perhaps the application of civil service qualifications to candidates for office would help to make democracy the practical system that it must be if it is to supplant autocracy permanently. If only competent candidates can qualify for presentation to the electorate, it will

not matter so much which one is elected. It would be simpler to improve the quality of candidates than to raise the I. Q. of the electorate.

You will not fail to note that from science in general, I have selected for special consideration the fields of economics and sociology. The reason is sufficiently obvious. Science is a product of civilization, and over our civilization of to-day hangs the threat of economic destruction, war and revolution. To that crisis science has contributed through the material applications of its work to production and to industrial and agricultural developments. In the face of possible economic and social catastrophe, it matters that research go on, but it matters more that what has been won be held and not lost. Hurricanes and fires will destroy laboratories as well as homes. It is possible for all companions in science to uphold the hands of our associates in economics and sociology in whatever efforts they may make to combat magic and magicians, and to bring the scientific method into a world of economic and social chaos. Not only scientists but mankind must learn to play the scientific game, for nature will play her part as destroyer if we fall afoul of her laws. She will turn hunger into despair, and pity into rage. It is not only in our laboratories that nature's workings are to be observed. She works unceasingly within us and throughout the body politic.

The scientist has a rôle to play in teaching the scientific game to others. Not in a spirit of reform or uplift, but in the spirit of scientists we must do our share to extend the scientific method of experiment and observation, of valid data, sound conclusions and constructive recommendations to our communal affairs, and to apply to our affairs what the world's history of the past and the world's experience of the present can teach us. Not to do so is to leave the world outside our laboratories to the magicians and their worshippers. In the ancient and medieval world magic could play its rôle the easier because of the lack or scarcity of science, but science and magic can not exist side by side in the modern world without serious conflict. Either science must supplant magic, or magic will wreck science. Scientists can not look on this combat with academic disinterest. They must play the scientific game intelligently, courageously and honestly against the magician as well as against their ancient adversary, nature.

SCIENTIFIC DISCOVERY AND HUMAN OUTLOOK

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NEAR the close of the nineteenth century Pasteur wrote: "In our century science is the soul of the prosperity of nations and the living source of all progress. What really leads us forward is a few scientific discoveries and their application." He said, also: "The cultivation of science in its highest expression is perhaps more necessary to the moral condition than to the material prosperity of a nation."

And now in the early years of the twentieth century important scientific discoveries are exerting a more profound and wide-spread influence upon human thought and action than perhaps at any previous time—this influence being upon the physical, the intellectual, the philosophical and the spiritual well-being of peoples everywhere. The many recent discoveries in all the important branches of science are being discussed to-day not alone by the specialists but by laymen in every walk of life, in every community. Questions are being asked and answers sought in every classroom, in the home, in the church, and on the street. What, it is asked, is the meaning—the constructive message—of the thousand and one facts which science has brought to us? And what of the to-morrow? Do not many of the questions give evidence of bewilderment, misinterpretation, lack of intelligent understanding of present-day problems and no clear vision as to the future? And all too often the scientific men themselves have been so absorbed in looking through their telescopes and their microscopes that they have not realized their obligations, not as scientific men necessarily but as human beings, to interpret, insofar as they are able, to their non-scientific friends the significance of the facts which they have discovered. As Agassiz once said, "Facts are absurd things until they are linked up with something." Is it not evident that we scientific men are not doing our proper share in helping men and women to get an adequate appreciation of the background of the present, a clearer understanding of the path along which the human race has come and some wholesome conception of man's future destiny?

Without attempting at once to give specific answers to any of the questions which have been raised or to make at this point any generalization with regard to human outlook, it will be helpful to all of us, I am sure, for me to present, if only in bare outline, some of the views which have prevailed in the past regarding Nature and some of the important concepts which are held to-day by scientific men based upon their detailed investigations, more particularly in astronomy and in my own special field of study, geology. Let me hasten to state that no consideration will be given at this time to scientific discoveries in their application to industry or to our material development, but our attention will be restricted to some facts of science as a key to the understanding of man's place in the universe and of the part he is destined to play in the years which lie ahead.

Study of primitive man—as, for example, the Cro-Magnons—who lived in caves probably twenty-five thousand to forty thousand years ago—has shown that they had already developed a distinct interest in nature. Witness their drawings of landscapes and animals on

the walls of their abodes. Dr. Henry Fairfield Osborn, the noted anthropologist, has stated that there is every reason to believe that this race "could compete in the art schools with any of the animal sculptors and painters of our day." Many thousands of years later, as revealed to us in the translations of the hieroglyphic languages of ancient civilizations, the Babylonians, the Assyrians, the Egyptians and the much younger stock of the Semitic peoples, the Hebrews, had developed the scientific attitude of mind and had an almost unbelievable knowledge of the celestial world. Literature written in the twelfth century B. C. reveals man's love of beauty in nature and "the great Pyramid of Gizeh," says Breasted, "is a document in the history of the human mind. It clearly discloses man's sense of sovereign power in his triumph over material forces." Then came Thales, the Greek, announcing that theory can and must be fitted to fact, which is the recognition of a foundation principle of all science. Centuries later came Copernicus, who put forward the view that our earth is not at the center of the universe, as had been held up to this time, but is one of several planets revolving around our sun, which is the center of our solar system. This new view of Copernicus, given to mankind only about four hundred years ago, "set the feet of man," said Newton, "for the first time firmly on the road leading to knowledge of the universe, and opened up a new epoch in the development of the human mind."

Now let us come nearer to our own day. Let us recall to our minds the scientific discoveries since Copernicus, but more particularly of the last fifty years. The scientific man is investigating to-day, is he not, everything which lies between the ultra-telescopic on the one hand and the submicroscopic on the other. He is working eagerly to satisfy his curiosity as to what is beyond the most distant star, what cosmic rays are, and what is within the tiny atom itself—the electrons, the protons, the neutrons and the alpha particles. Scientific men to-day have faith not alone in things which can be seen but in things invisible. We are indeed living in what has been called "The Wonderful Century."

What, then, are some of the significant facts which are the result of scientific discovery? What are some of our present-day concepts about the universe, our solar system, our earth and the history of man? Simon Newcomb once said: "If it be true that in nature nothing is great but man, in man nothing is great but mind, then may knowledge of the universe be regarded as the true measure of progress." It is now well known that our sun is but one star of millions of stars which circle about one another in a star system, and that this star system is but one of millions of star systems in the universe. If a star in one of the most distant star systems should suddenly explode it would take light which travels 186,000 miles per second more than 200,000 light years to get the news to us on the earth. The immensity of space is beyond the comprehension of the human mind. Dr. Hubble, of Mount Wilson Observatory, has estimated that the universe apparent to man does not extend more than a certain multiple of millions of trillions of light years from the earth. Was it not Pascal who said, "The universe is an infinite sphere with center everywhere and surface nowhere"? But enough of the universe, you say. Give us some facts about our own solar system and about the earth, the planet on which we live. Such facts will be of more direct concern to us. It was Herschel who suggested a method by which a proper conception could be gained of the relative sizes and space relations of the planets of our solar system. If, he said, our solar system were represented within a sphere, with a radius of 1¼ miles, and if our sun were

represented at the center of the sphere by a globe two feet in diameter, it would be possible to represent the planets which revolve about our sun, as to spacing and sizes, on the 1¼ mile radius. In such a scheme Neptune, the outermost planet (until the discovery of Pluto recently), would be at the end of the radius and would be represented by a plum, Uranus by a cherry ¾ of a mile from the sun, Saturn by a lemon ⅔ of a mile from the sun, Jupiter, the largest planet of our system, by an orange ½ of a mile from the sun, Mars by a pinhead 327 feet from the sun, our earth by a pea 215 feet from the sun. Nearer to the sun than the earth would be Venus and Mercury, the former represented also by a pea only 82 feet from the sun, and the latter, Mercury, the smallest planet, by a small seed two feet from the sun. Let me repeat, our earth would be a pea 215 feet distant from the sun. How small a part of our solar system is our earth! And, as has been stated already, our solar system is but one of millions of solar systems in the universe.

And now for some facts about the earth itself. The geologist, for more than one hundred years, has been unraveling the fascinating story of this planet on which we live. Dr. J. C. Merriam, of the Carnegie Institution of Washington, himself a distinguished geologist, has said "The geological record is the greatest historical document of all the ages"; and the nature poet, Walt Whitman, has written:

> The earth is rude, silent, and incomprehensible at first,
> Be not discouraged—keep on—there are divine things well enveloped,
> I swear there are divine things—more beautiful than tongue can tell.

The books in the library of the earth have now been read. The manuscripts are the rocks themselves—the limestones, the sandstones and the shales—with their included records of the life of the ancient seas and lands. The rock-forming processes have been active throughout the ages. By one of these processes, called gradation, layer upon layer of rock has been laid down—superimposed books, the oldest at the bottom to the youngest at the top.

The face of the earth throughout its history has been undergoing change continuously. The areas of land and sea have been ever shifting. Running water and other agencies have been tearing down the continents, carrying the materials of erosion into the sea, and there depositing them. Each day the Mississippi River carries in its waters and deposits in the Gulf of Mexico more than a million tons of sediment—four hundred million tons a year. If nine hundred trains, each of fifty cars and each car loaded with 25 tons of sediment, were running parallel to the Mississippi River day and night without stopping, these trains could dump into the Gulf only the amount of sand and silt that the Father of Waters is now carrying. The shore lines of the oceans are never the same during any two successive seconds. The only permanent thing is change, and so it ever has been throughout the earth's history. As Tennyson has written:

> The hills are shadows and they flow
> From form to form and nothing stands;
> They melt like mists—the solid lands
> Like clouds—they shape themselves and go.

Where the mountains now are the seas have been time and time again. Widely distributed on the continents are rocks with their cemeteries of past life.

> There rolls the deep where grew the tree,
> O earth, what changes thou hast seen!
> There where the long street roars hath been
> The stillness of the central sea.

Let us return to our library. The history involved in the records of the earth when traced back and back to the most ancient record available for study at the face of the earth has been estimated from our most reliable data to be

probably 2,000 million years. The geologist has found it convenient to divide this immense length of time into five great eras, during each of which there was written in the rocks what we may choose to call a volume in the library of the earth—five volumes in all, in which is found the story of the onward, upward, march of life from lowly organized forms to the highest types of animal and plant life which inhabit the earth to-day. Volume I, the most ancient part of the available record, may have involved 800 million years. The oldest chapters of this volume indicate clearly that life was already in existence and possibly had been for hundreds of thousands of years, even long before the earth had attained its full size.

From Volume II, which involved also a very long time—probably more than 650 million years—the kinds of life which frequented these ancient seas have been determined. These and the earlier manuscripts of Volume I have been much changed by great heat and great pressure resulting from profound earth movements and extensive volcanic activity. In Volume III, abundant and wide-spread life is found—invertebrates—marine and land forms—and vertebrates—fishes, amphibians and reptiles. Trees and plants, too, of great interest to the paleobotanist, were distributed widely. Some of our most important coal fields bear witness to this chapter in the history of vegetation on the earth. The time included in the making of Volume III was not as great as that of the preceding volume, probably not more than 350 million years. In Volume IV, of still shorter duration—involving probably not more than 140 million years—the reptiles were the masters of the day; not only were they present in great numbers, but they were of huge size—sluggish creatures, some herbivorous and some carnivorous, all with deficient brain capacity. The struggle for existence was terrific. Some tried to maintain themselves on the land, some attempted to adapt themselves to life in the sea, and some developed the ability to fly—flying reptiles with a spread of wing of twenty feet. Nature surely at this time tried an unusual experiment—she resorted to the development of the maximum of the physical with a minimum of the mental—size without intellect—and the result was failure. But perhaps we should not say failure, for did not John Burroughs once say "Nature always hits the mark because she shoots in all directions."? These colossal, lazy dinosaurs and related forms passed from the stage as the last chapter of this Volume IV was being written. While these huge reptiles were still abundant, birds were evolved and a few small mammals. What of Volume V? It is only in this volume which goes back to about sixty million years from the present that the paleontologist finds evidence of the rapid and wide-spread differentiation of the mammals—the haired animals. The most highly organized of these mammals—the Primates—were living when the earlier chapters of Volume V were being written, but man, the highest of the Primates, came upon the scene only comparatively recently, in that period which lies just back of the Recent, geologically—the Pleistocene or Glacial Period. And as yet the cradle of the human race has not been determined with definiteness. The earliest remains of human species have been found as widely distributed as Java, Southeastern Asia, Germany and England. And, according to the most reliable estimates, man has been on the earth at least a million years. But he is a resultant of a history linking him back and back to the beginning of life itself; yes, and still farther back to things inorganic. He is made of the stuff of the universe itself. Only as we come to understand the universe can man be fully understood—universe, solar system, earth, life, man—

infinite space, infinite time, and, shall we say, infinite life.

A fire-mist and a planet; a crystal and a cell;
A jelly-fish and a Saurian, and caves where the cave men dwell;
Then a sense of law and beauty, and a face turned from the clod;
Some call it Evolution, and others call it God.

Onward and upward to man—man a resultant of the processes of the ages—weak physically but strong mentally—with power to look back and unravel the line of his descent, to analyze himself in relation to all other life with which he is associated, and to conceive and plan his own future. Another of nature's experiments, you say, but this time brain power, not brute strength is at the helm.

And, what of man's future? What is the human outlook? What will Volume VI reveal? Surely the answer to this question is of vital concern to all of us, but more especially to those who are still young—preparing to play their parts in the great drama of life. Does our knowledge of the past and of the present enable us to make any trustworthy prediction as to the future? Chamberlin, the world-famous geologist, said: "The forecast is at best speculative, but an optimistic outlook seems more true than a pessimistic one. An immeasurably higher evolution than that now reached, with attainments beyond present comprehension is a reasonable hope.

"The forecast of an eon of intellectual and spiritual development comparable in magnitude to the prolonged physical and biotic evolutions, lends to the total view of earth history great moral satisfaction, and the thought that individual contributions to the higher welfare of the race may realize its fullest fruits by continued influence through scarcely limited ages, gives value to life and inspiration to personal endeavor." And Sir James Jeans, the astronomer, about whom much is being heard in these days, has written in one of his recent books: "By what light we have, we seem to discern that the main message is one of hope to the race and of responsibility to the individual—of responsibility because we are drawing plans and laying foundations for a longer future than we can well imagine." And Conklin, the well-known biologist of Princeton University, has predicted that the next great step in human progress will be social—the development of social interrelationships of the human race—the different races of mankind learning to live with one another without destroying one another.

We are living in the aftermath of a great war. In the words of General Smuts: "Humanity has struck its tents, and is once more on the march. A new adventure is beginning, a new search for justice, perhaps—who knows? A new Renaissance."

Surely man has the mental power and insight to enable him to realize that his future can be best insured by the cultivation of the spirit of cooperation and the abandonment of "the tooth and the claw" of his less endowed relatives of the past and present.

Only through the united efforts in research of scientific men, humanists, philosophers and theologians, in every country of the world, will we gain a still better understanding and a clearer appreciation of what man is and of what God is. Then will we be able perhaps with clearer vision than at present to interpret the meaning and purpose of our own lives and to plan effectively for man's future welfare.

THE TROPICAL AMERICAS[1]

ETHNOGRAPHY AND MEDICAL GEOGRAPHY

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FROM the medical standpoint, the western hemisphere falls into natural geographic rather than political divisions. The major portion of South America, all Central America and the southern fringe of North America properly come within the scope of tropical climatology. This tropical region in general consists of two major and three minor cases. Of the major areas, the smaller, of greater importance now, comprises the shores of the Gulf of Mexico and the Caribbean Sea with its islands, well called the American Mediterranean. The greater in extent, and perhaps of chiefer importance in the future, is the watershed of the Orinoco and Amazon Rivers. The three minor areas are: (1) The watersheds of the Plata and São Francisco Rivers, together with eastern coast of South America, (2) the mountainous and high plateau regions extending along the backbone of the continents from Bolivia through Central America into Mexico and the southwestern United States, and (3) the narrow coast lands bordering on the Pacific.

GENERAL

Disease incidence and even more, disease control, in the Americas are determined by two great factors. The first is the actual topographical climate and the second is the influence of the various immigrant races. Ethnologically, we find the primitive American Indians in related types distributed thinly throughout both continents with records of special concentrations of culture and population in the mountains of Mexico and upper South America. These aboriginals have been replaced, overlaid or intermixed with three general immigrational types. These streams of immigration have followed a peculiar course in general zones. North of the Mexican Gulf the north European or Nordic race and culture and psychology prevails. From the upper Mexican boundary, the rest of this district has been the site of Latin or Mediterranean influx, with Spanish as the language basis of all countries, except Brazil, occupying nearly half of South America, where Portuguese prevails. The elements of tropical climate, added to the Latin character of the conquerors and the accessibility of Africa, made easy the spread of slavery through the entire region under discussion. The result is a heavy Negro and Negroid percentage in the population.

Spanish colonies were established especially on the River Plata, on the northwestern corner of South America, in Mexico and in Florida. Portugal colonized the east coast of South America and here African slaves were especially brought in. Whatever the respective merits of the respective claims to the discovery of America, the fact remains that the indomitable and unscrupulous will of Columbus first brought the western hemisphere to the attention of Europe. Sailing from Palos in Spain, he fulfilled the ancient prophecy of the Spanish-born Seneca, who,

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more than fourteen centuries before, had said that the ocean would loose its hold on things and a vast new land would be revealed and Thule would not remain ultimate. So, after Columbus, the "Ne Plus Ultra" across the Pillars of Hercules on the coins of Spain was changed to "Plus Ultra," and for three hundred years "More Beyond" was the watchword of the gold-maddened Spanish conquerors, who ruthlessly destroyed the ancient civilizations of tropical America, replacing them with colonies of exploitation and an age of piracy, destruction and brigandage.

Two pregnant speculations arise. Firstly, what different results might have followed if America had been discovered two hundred years later or if America had first discovered Europe. Under these conditions the character of colonization of tropical America would conceivably have been so different as to influence profoundly the matter of disease control in these regions and thereby the development of their resources in foods and in natural wealth. Secondly, if north European races had discovered and controlled the American tropics, we can readily imagine different results in character of colonization and development, when the desire for relief from persecution and for new permanent homes furnished the basic purpose. As it is, we have to deal with predominant Latin influence through all South America and up to the boundary of Mexico. In the tropical sections, this is mixed with the aboriginal Indian population and the African Negroes.

Ethnology

The ethnologic units of the New World thus include the North European, the Latin, the Negro and the Indian. The North European requires no detailed description. His aggressive, industrious, evolutional force speaks for itself. It remains only to note the effect on his characteristics of prolonged exposure to hot climates and extended association with tropical peoples. Nowhere in the world are the results of such contact more important and their understanding more critically necessary than in the regions under discussion. The principles involved will be given more extended treatment elsewhere under the separate heading of the white man in the tropics.

The Latin temperament is more a product of a warm climate and its contribution to American culture in the broad sense is extensive and valuable. It is the contribution of direct emotional expression, of high appreciation of esthetic values, of warm enthusiasms, of intense personal loyalties, of great potentialities for keen thinking and originality of thought and of hard-working brawn. These elements are present throughout tropical America, but they have been handicapped by their corresponding weaknesses and have reacted poorly to climate and to the local populations. Languor and insufficient application have too much won the day. Under proper influences of climate and human contacts, the Latin character reaches untold heights. Failing these, it degenerates to the lowest of its associates and is submerged by the lethargy and monotony of its environment. This is largely what we find in the tropic zone of the New World. Greed, evanescent schemes, political instability, economic beggary, selfishness, insincerity and duplicity too easily creep in and are only held in check by the stronger Latin social units and by outside contacts.

These elements make the problem of disease control very great, and result in a need for public health work on a totally different basis from that in other hot climates. Disease vectors, disease incidence and disease cure and prevention become decidedly ancillary to the problem of dealing effectively with the

Latin temperament in a tropical climate. Probably the solution will be found by tracing our analysis back again to improved contacts with more effective human institutions, and to demonstration of the economic value of sanitation and disease prevention.

The American Indian

Few ethnological battles have waged with greater brilliance and keener strife of contending factions than that over the problem of the origin of the American aboriginals. For the present purpose we are not concerned with deciding whether they came from Mongolia by way of the Aleutian Islands; from north Europe by way of land-ice bridges across Greenland; whether they developed locally, coequal with human origins elsewhere in the world; or whether they came both by island bridges in the north and also by fortuitous and accidental voyages across the Pacific from Japan, China, Malaysia and the Pacific islands. This last seems the most explanatory theory.

In any case the fifteenth century found a thin sprinkling of these generally reddish-skinned natives over all of both continents. To these Columbus applied the name of Indians, and priority as well as usage have established it in spite of its complete inappropriateness.

There are some evidences of a paleo- or at least neo-lithic race in North America, as in the Delaware River valley (H. W. Haynes, "Prehistoric Archeology of North America," in Winsor's History of America) which became extinct and had no relation to those later natives known as Indians. One of the chief difficulties in tracing the antiquity of the Indians has been the absence of associated domestic animals other than the dog (H. H. Howorth, "The Mammoth and the Flood"). Regardless of their origin and the length of their residence, at the time of the discovery, they were uniformly distributed through the American continents from the Esquimaux to the Fuegians. They had a general resemblance in color and configuration of head and face which showed a wide molar arch, medium nasal aperture, low orbital indices and a generally broad face (Brinton, "The American Race"). Their average cranial capacity is above that of the Negro and considerably below that of modern Parisians. Individual capacities have been measured of a size not exceeded by any race. (L. Carr, quoted by Brinton). The skin color is copper-like, reddish or cinnamon hued, a brown with an element of red. The darkest are not black and the lightest are not white. The hair is generally straight and coarse, dark but not black, heavy on the head, scantier on body and face. It may be fine and silky. (See Brinton, "The American Race," for full exposition). The average stature is probably under the European average, but there are many tribes in which there is a fair percentage of large individuals approaching the six-foot height. There are no dwarfs or pigmies among them, with a few exceptions in the Amazon jungles. Small hands and feet with long arms are characteristic.

Various factors help explain the remarkable similarity of types throughout both continents. In general, the mountain systems and rivers of the western hemisphere are arranged longitudinally, making for geographic ease of migration in line with the continental axis and permitting early free diffusion. The chief exception to this rule is the Amazon River, which flows from west to east, but which in its long lower course is more an estuary than a river. Its chief tributaries follow the rule given. Another element making for uniformity is probably to be found in a general com-

mon origin of the Indians from a single racial type.

In mental endowment the Indian can be judged from two standpoints. In the first place, the testimony of many travelers and observers of scientific ability agrees in ascribing to many tribes on both continents a position of mental capability below but comparable with the white race. In the second place, judgment by degree of achievement shows some interesting comparisons. It is easy to fall into the error of considering what is different as inferior. This is a common fault in our estimation of tropical and especially of oriental races. The American Indians showed considerable ability in political organization and government. The Iroquois League in the north and the Incas in the south were eminently successful states of long duration, definite policies and wide dominion. Full-blooded Indians under modern conditions have been active in this line, as President Benito Juarez, of Mexico, President Barrios, of Guatemala, and many others. In architecture, art, agriculture, mining, as well as in personal qualities, the Indian has shown and shows great capacity. He is, however, decidedly not adaptable to a foreign culture or civilization.

Cultural advancement has not been a matter of race or tribe but primarily of location. With a close ethnic unity the Indians none the less exhibit a surprising variation in culture and achievement. This extreme variation extends to the languages, which are very numerous and to a high degree dissimilar. We find the explanation of their advancement by considering the locations where it has been most marked. The eastern United States and the high plateau regions of Mexico, Yucatan, Guatemala and the northern Andes all enjoyed a healthful climate, with necessary variations between heat and cold. They afforded reasonable natural protection from enemies. They were reasonably free from insect vectors of disease. They were sufficiently isolated from human contacts with contagious disease. Conditions of climate, savannah and water supply permitted agriculture. In these sections all the local tribes shared in the advancement. It was not limited to a certain tribe or race. It was a result of favoring environmental factors.

So outstanding is this situation that it raises at once the query as to why the Indian could not again respond to a favoring environment by cultural achievement as great, if not of necessity along the same lines, as 400 to 1,000 years ago. Where climatic conditions are now suitable, improvement of economic and political status becomes, therefore, a part of public health work, since disease control is based on intelligence, and the evolution of intelligence in the past has been rather determined by location than by particular personal gifts. Where climatic conditions are unfavorable, sanitation and public health must be introduced first from without, and imposition of decreased disease risk becomes the primary civilizing factor.

Three great facts must be remembered in dealing with the American Indians. All are based on the ethnic unity of all the tribes north and south. All recognize the tremendous diversity in languages (estimated at from 126 to 400 in number), in culture types and in advancement. The Mayan, Aztec and Incan cultures, at one extreme, were emerging into civilization, while the northern tribes were well above the level of savagery and the southern tropical tribes of jungle and savannah were still savage. In general, the Indians were slowly rising in civilization, the extent and rate of the rise being largely determined by their environment.

(1) The matter of early relations between Indians and whites. No known

race of men surpassed the North American Indians in absolute cruelty. The nomadic tribes had no true claim to the territory over which they roamed. When opposed by home-seeking white men of a superior civilization, their atrocious cruelty merited the sternest repression possible. They were masters of a new art of warfare which the whites learned from them with revolutionary results in world methods of warfare. The writings of Thwaites, Francis Parkman and Theodore Roosevelt should be consulted for more detailed treatment. After the warlike northern tribes, we consider the more agricultural tribes of the warmer climates both north and south, who were semi-savage and barbarous. These races made little effective opposition to the conqueror and were ruthlessly pushed out of the way of the whites. Finally, we consider the races of the mountain plateaus of Mexico, Central America and the northern Andes, which represented the acme of Indian culture and civilization. In all their explorations and conquests, covering the huge territory of South and Central America, Mexico and the lower third of what is now the United States, the Spanish conquerors were actuated by one consuming motive only—the inordinate lust for gold. This led to absolutely unscrupulous destruction of the best Indian cultures, in Mexico and Peru, and to a type of colonization for exploitation which was short-sighted, unmindful of native populations, and not designed for permanent new homes. Associated with this was the principle of black slavery, whose extension to the Indians was attempted, largely without success.

(2) The highest possibilities of the Indian in civilized advancement were realized among the Incas and the Aztecs and associated races of Mexico. This civilization was, at its best, greatly inferior to European civilization of the day and has been exaggerated and idealized. They had, indeed, an organized city life, excellent stone architecture, hieroglyphic writing, the beginnings of phonetic writing and a type of lavish luxury. Even the highly advanced Teycucans, who preceded the Aztecs in Mexico, did not reach the level of European civilization either in the accomplishment or in elements of permanence or continued progress or in contribution to human welfare. In passing judgment, we must, however, remember constantly the risk of considering as inferior what is merely different. In any case, the best of Indian culture was destroyed by the Spanish conquest and has not yet been resurrected. The descendants of those days are ignorant, superstitious, devoid of ambition, taking pleasure chiefly in alcohol and dancing.

(3) Finally, it is a matter of importance that the American Indian races have made a large contribution to the present constitution of the nations of the western continents. This is much less marked in the United States than to the south. To a considerable degree, however, the North American Indians have been absorbed into the white population. Starting with the north Mexican boundary, the aboriginal races are of immediate prominence in every nation except Argentine and Uruguay, which are almost entirely white. Of the fifteen millions of Mexico, Bryce estimates eight millions as pure Indians, six millions as mestizos and one million as Spanish. (See James Bryce, "South America," 1913). Paraguay is purely Indian and speaks Guarani. In general, Bryce accepts forty-five millions as the population of South America, of whom about one fifth are pure Indians, and about one third mestizos. Excluding Brazil, with its large Negro fraction, white Uruguay and *nearly white* Argentina, and confining "our view to the other eight republics in which the Indian element is

larger, a probable estimate would put the number of pure Indians at more than double that of the whites, and a little less than that of the mestizos." It is to be remembered also that the mestizos rank with the whites and together form the ruling class, socially and politically, the Indian element "being passive and in a political sense outside the nation."

The Indians furnish the rank and file of armies, fighting cheerfully and methodically for causes they care nothing about, and they also are the chief reliance for common labor.

Negroes

There are approximately eight to nine million Negroes and mulattoes in South America—chiefly in Brazil. Fewer of them are found in Peru, where the "Zambos" represent Indian-Negro mixture, and a scattering in other countries. Their preponderance in Brazil is due to the old Portuguese slave trade from Africa. A second center of Negro population is found in the West Indies. In these islands slavery came with the Spanish, who forced the Indians to work in mine and on plantation. African slavery followed and the predominant blacks of to-day are descended from African slaves chiefly brought by the Portuguese and Spanish. The black republic, Haiti, and the nearly black Santo Domingo are interesting examples of self-government, virtually under foreign protectorate, and are very backward politically, socially and economically. The third great Negro center in the western world is in the United States. Here is found the largest, most progressive and most advanced group of Negroes in any country outside of Africa. They number approximately eleven millions, and constitute about one third of the population of the Southern states. Since the Civil War, while it is possible that the lowest tenth has retrograded, it is certain that the highest tenth has advanced immeasurably. Miscegenation is relatively far less common than in the West Indies and Brazil. Many Southern states forbid marriage between whites and persons who have one eighth or more of Negro blood. The mulatto class represents to a considerable degree illicit unions. Color prejudice is strong, and since the end of post-bellum reconstruction, in 1877, there has been a practical disenfranchisement of a large portion of the Southern Negro population, with probable advantage to both whites and blacks. While large numbers of Negroes have migrated to northern states, as to New York especially, climatic conditions make the south his best United States habitat. The Negroes constitute economically an important unit of population in the United States. Their future has good prospects, but the question of racial absorption is very doubtful and equally important.

The Mexican Gulf Coasts

The coastal plains of the Mexican Gulf begin with the peninsula of Florida and terminate with the opposing peninsula of Yucatan. In that portion lying within the United States, three geographic features are of medical interest. (1) The Floridan peninsula has an underlying, easily eroded limestone base, which leads to much underground drainage of the lowlands with many sinkholes. The great Everglades marshes dominate the southern portion, while at the tip is found a series of coral reefs growing out against the gulf stream, which brings their food supply. (2) The coastal plain in Alabama and parts of Mississippi and Texas is low and rich, averages 150 miles in width and shades off into lagoons and marshes. (3) The huge embayment of the Mississippi River extends up the river course for some 500 miles and includes the great delta region. The Mis-

sissippi drains one third of the United States, and its lower course has a fall of only half a foot per mile. It carries annually into the Mexican Gulf a load of soil which would be 312 feet deep over one square mile. Its load of alluvial deposit is a great factor in its tendency to wander into new channels and in building up the delta itself. At low water, 300 miles from its mouth, the river level is little more than 5 feet above the level of the Gulf and in the latter the tidal variation is less than 15 inches, making the river simply a fresh-water lake nearly at sea-level. At high water a rise of 50 feet gives sufficient head to carry the enormous volume of water into the Gulf.

The great system of dykes or levees, nearly 1,500 miles in length, is a distinctive feature of the Mississippi, together with the huge floods which become maximal at five or six year intervals. More than $70,000,000 has been expended by the United States Government alone on control of this waterway to keep it navigable and limit flood damage, between the mouth of the Ohio River and the Gulf. This is additional to the expenditures of the adjacent states. The Mississippi River is of great medical importance, because of the wide extent of its flood basin, much of which is habitable under levee protection; because of the marshes, lakes and low grounds which border it; because of its again increasing importance as a commercial waterway; and because of the subtropical climate in which its lower course lies. From its mouth to the source of its great tributary, the Missouri, it is the longest river in the world, 4,221 miles. It is comparable to the other major water courses of the world. Its floods and the nature of its alluvial flood basin raise problems for the sanitarian similar to those of the Yangtse and Hoang-ho. When pressure of population has increased, these problems will be duplicated in the Amazon, Orinoco and Congo. Its huge delta, with salt marshes gradually giving way to fertile black land, is comparable to the delta of the Nile, which is 100 miles deep and 155 miles wide. Backwaters, marshes and periodic flooding raise problems of insect control, sewage disposal, water supply and atmospheric humidity which are primarily sanitary, that is, medical, and on which its civilization and habitability depend.

West from the Mississippi embayment, the coastal plain is marshy towards the sea through Louisiana and the Texan coast, gradually blending through low hills with the hot dry plains of Texas. Cypress swamps and alligators, mosquitoes and scattered huts and villages, built on higher ground or piling, express the landscape. This coast is continuous with the coastal hot belt of Mexico, reaching its insanitary apotheosis in the hot, humid, healthless Rich City of the True Cross, Vera Cruz, whose site and name were determined by the avarice and religious fanaticism of Cortes, who here found fertile soil, a good harbor and a base for attack on the rich Aztecs, but no sanitary or health advantage. Vera Cruz has been one of the disease centers of the Mexican Gulf throughout its history, combining its rare advantage for disease incubation with a population indifferent to sanitation and tolerant of all disease-fostering influences. In the United States, Mississippi, Arkansas and Louisiana are only exceeded by Florida in extent of swamp lands.

The embayment and delta of the Rio Grande reproduce on a smaller scale the outlet of the Mississippi River. Large rivers are not found in Mexico or Central America, because the high plateau which is dry and largely treeless leaves only a narrow belt of lowland, the tierras calientes. Yucatan has no rivers. Many of the Gulf Coast rivers are navigable for short distances, the Orijalva in Ta-

basco, even for 93 miles. They are largely obstructed by bars and silting. Many navigable lagoons border the coast and a remarkable series of banks has been built several miles off the north coast of Yucatan by the Gulf Stream. Owing to silting and bars, Mexico has very few good Gulf ports, Vera Cruz, Tampico and Coatzacoalcos being noteworthy.

The tierras calientes, or hot lands, include the narrow Pacific and Gulf coastal plains, the isthmus of Tehuantepec, the states of Tabasco, Campeche, part of Chiapas and Oaxaca and the Yucatan peninsula. In this belt the elevations rise to 3,280 feet at most and, except in Yucatan, the fertile soil and heavy rainfall, approaching 100 inches annually in Vera Cruz, result in dense forests of marvelous richness. The unhealthiness of these lowlands alone prevents aggressive development commercially. Yucatan peninsula is in general under 200 feet above sea-level. It is largely unforested, has a porous soil, hot sun temperatures cooled by fresh sea breezes, abundant rainfall in the wet season, which, however, is quickly drained off, and a long dry season. It has, therefore, a fairly hot, dry and healthful climate, similar to that of the Pacific lowlands of Sonora. Only in the extreme north of Mexico, above the 28th parallel of latitude, are there four distinct seasons. For the rest, the lowlands have a rainy season from May to October and the balance of the year is the dry season.

Above the tierras calientes rises the tierra templada or temperate zone, to an altitude of 5,577 feet. From this up to 8,200 is called the tierra fria and includes the higher Mexican plateau, with hot sun temperatures, rare frost and a really subtropical climate and flora. Animal life in Mexico is interesting in that the tropical species of the south and the Gulf coast extend well up the warm coastal plain into the United States, while the temperate climate animals of the United States are found extending far south through the high central plateau region. In the southeast, the fauna resemble the Amazonian types. Of the plant life, chief mention should be made of the agave (including the "century plant") or maguey of the plateau, from which the national drinks, pulque and mescal, are made. While these plants are important sources of textile fibers, their medical importance lies in the heavy and wide-spread use of the alcoholic beverages made from their juices. Mixed blood, climate, disease and alcohol are the great foes of Mexico. The forests of the tierras calientes are among the finest in the world. They include 114 varieties of trees and cabinet-woods, 17 oil-bearing plants and over 60 medicinal plants and dye-woods indigenous to Mexico. Here are found jalap, ipecac, sarsaparilla, rubber and a large number of gums.

The Caribbean Sea

Among the most adventurous and romantic chapters in the history of America is the story of the Caribbean Sea, well called the American Mediterranean. Its northern limit is at the Yucatan-Florida strait. Its western and southern shores wash the tropical coast of Central America, Colombia and Venezuela. It is separated from the Atlantic by a chain of mountain tops reaching up into the West Indian islands, stretching from Trinidad to Florida. Following the Spanish Conquest, this area was colonized and claimed in its entirety by Spain. Spanish monopolies in trade, export and industry led to vigorous opposition by adventurers and traders from England, France and Holland, whose private exploits and greed for the riches of Spanish America grew rapidly into the loosely confederated system of buccaneers (which see) who terrorized tropi-

cal American waters in the seventeenth century. The buccaneers were actuated by two principles, bitter hatred of Spain and greed for the wealth of the Caribbean countries, including the products of the South American mines which came across the Panaman isthmus to Porto Bello for transshipment to Spain. Finally disappearing as a result of their own methods and by the treaty partitions of territory between the powers concerned, the buccaneers none the less left their mark on this great region both historically, politically and socially.

The West Indian islands are divided in sovereignty between Great Britain, which holds chiefly Barbadoes, Bahamas, Jamaica and the Lesser Antilles; France, which holds Guadeloupe, Martinique and part of St. Martin; Holland, holding several small islands; the United States, with Puerto Rico and the Virgin Islands; and the three republics of Santo Domingo, Haiti and Cuba. Climate is greatly influenced by altitude, as is the case in all tropical countries. Out of some 100,000 square miles of island territory, nearly 16,000 square miles lie above 1,500 feet in elevation. Except the Bahamas, all are between the isotherms of 77 and 82 degrees Fahrenheit. Coolness is found in the higher areas with typical tropical conditions below. The seasons consist of a short wet season of two to six weeks, beginning in April, followed by the short dry season, reaching its climax in the extreme heat of July. With October the heavy rains set in, often associated with the terrific and destructive hurricanes. (See Chapter—Disasters, etc.). These are known as the "hurricane months." From December to April comes the long dry season. The average annual rainfall is well over 60 inches.

The great prosperity of these islands is not due to mineral deposits, in which they are quite deficient, but has followed the introduction of sugar-cane in the middle of the seventeenth century. Cocoa, fruits and cotton are also of major importance. These facts all have important medical results, as the tropical climate, with the predominant Negro and Latin population, extreme fertility of soil, exposure to earthquakes and hurricanes, etc., make unique public health problems. Sanitary control of the tropics has been remarkably demonstrated, as in Jamaica, Havana, Puerto Rico and elsewhere. The control of sanitation and disease hazards, together with the peculiar local climatic advantages of many parts, makes these islands of importance as health resorts and as areas of permanent settlement by the white race.

Little need be added with reference to the Caribbean coast of Central America, where is found an extension southward below Yucatan of the narrow, hot, wet, coastal plain of Mexico. Honduras has a valuable frontage of 60 miles on the Bay of Fonseca on the Pacific, a deep harbor unsurpassed in the world. Several fine interior valleys provide reservoirs which feed the important rivers flowing into the Caribbean, many of which are navigable 60 or more miles inland. The largest of these is the Segovia. The Ulna River drains about one third of Honduras, rising in the remarkable plain of Comayagua, a great transverse valley, 40 miles in length and 15 miles wide at the most, out of which flow through broad valleys the Goascoran into the Pacific and the Humuya, a tributary of the Ulna, into the Caribbean. This low broad valley makes a natural pathway from the Atlantic to the Pacific. As throughout Central America, there are two seasons, a wet and dry, the latter from November to May. The interior highlands, with their fine valleys and lakes, have a delightful climate, at Tegucigalpa, the capital, the annual range being from 50 to 90 degrees.

In Guatemala the plain of Peten in

the north is worthy of special note. This plain is essentially a part of the Yucatan peninsula, is grass- or tree-covered, in many parts fertile and well watered, but is inhabited chiefly by a few Indians, averaging less than two per square mile. This contrasts with one of the thickest known jungles along the Motagua River. The malaria of the coasts is not prevalent elsewhere and the healthy interior has the usual salubrious climate of tropical highlands. Only the necessary seaports are on the coast. Rainfall ranges from 195 inches at Tual on the Caribbean to 27 inches and less in the interior. The population of Guatemala is of special medical interest because of the low death rate and high birth rate, leading to a rapid increase. Guatemala contains about one third of the population of Central America. Three fifths of these are pure Indians, indolent, unthrifty and addicted to gambling. Of the remainder, pure whites are a small minority among the mestizos. The numerous Italian colonists are looked down on by the Indians because of their industry and thrift. Half the Indian births and one third of the white births are illegitimate. Alcoholism is prevalent among the Indians, whose chief diet is of corn, beans and bananas, with occasional fresh pork. The lack of development and the backwardness of Guatemala, rich as she is, are due to the political insecurity and to numerous and dangerous earthquakes, both of which interfere with capital investment and advance of civilization. Guatemala City, the capital, was destroyed by earthquake in 1918. German colonists before the Great War controlled most of the plantations and half the exports of coffee were to Germany. Guatemala is surpassed in coffee production only by the East Indies and Brazil. (Encyc. Brit., XI).

Costa Rica also has a high tableland, cut by lofty ranges, descending precipitously to the Pacific and more gradually to the Caribbean, the latter shore being low, sandy in places, with marshes and lagoons and no harbor. The proximity of the two oceans make the climate variable, but the three great belts of hot, temperate and cool climate can be traced here also according to altitude. The rainy season, from April to December, has a strange interruption of two or three weeks of drouth in June, called the Veranillo de San Juan. In general, it is remarkably healthy for a tropical land, malaria and rheumatism in the lower levels being most prevalent. The population has a higher percentage of Spanish blood than elsewhere in Central America, and the black admixture is extremely small. Earthquakes, landslides and cloudbursts are its great natural enemies. Its great human asset is its relative political security and freedom from revolutions, largely a result of the considerable number of landed peasant proprietors.

Nicaragua has a Caribbean coast-line of 300 miles, which is low, swampy and exhibits the worst features of tropical climate. All its rivers empty into the Caribbean Sea. While there is a crowded galaxy of volcanoes along the Pacific, earthquakes are less severe than in the countries to the northward. This is compensation to some extent for its lying in the Papagayos tornado belt. Its predominant interest lies in Lake Nicaragua, a hundred miles long and forty-five wide, lying at high water 110 feet above sea-level. The influence of the trade winds causes a curious rise and fall on this lake, which for a time was thought to be a tide. Lake Nicaragua, with its valleys leading to the two oceans, is the third natural roadway between the Pacific and Atlantic, and ranks next to the Panaman Isthmus in importance. The two other roadways are at Tehuantepec and the Honduran plain of Comayagua. Bluefields, named after the Dutch corsair, Blieuveldt, and

Greytown are the chief Caribbean ports for the interior and Managua, the capital. The uplands of the interior are healthy, in spite of a generally heavy rainfall, often exceeding 100 inches and at Greytown on the coast approaching 300 inches. Bizarre racial blends are common among the people, Indians with fair skin and blue eyes being seen along with others having Indian or Negro coloring and European features. With practically no immigration, the population is yet increasing rapidly. Nowhere on the American continents have revolutions and political upheavals been as frequent as in Nicaragua. For 225 miles the Caribbean coast of Nicaragua is known as the Mosquito Coast, from the name of the chief inhabitants, the Misskito Indians. After a more or less independent existence as a protectorate of England, from its first colonization in 1630, this territory in 1804 became a province of Nicaragua.

Only a few points need to be noted with reference to Panama, including the ten-mile strip of the Canal Zone. Panama is 41 to 118 miles in width, with a length of 430 miles. Low mountains, the meeting of the Pacific trade winds with the winds from the Caribbean leading to heavy rainfall, and the wide-spread jungles and forests, with an irregular broken hinterland, are of importance. Numerous islands, over a thousand in number, are found off the coasts. While there has been no volcanic activity within historic times and apparently not since the Pliocene Tertiary age, earthquakes are frequent and severe, except in the region of the Canal Zone.

Panama Canal

For detailed description of the Canal Zone with its special problems of sanitation, hygiene and quarantine, reference must be made to numerous special volumes and articles. We can review here only the general features. The canal is really a huge water-bridge across the isthmus, 85 feet above sea level, entered by locks at either end, and fortified heavily. It is a United States military post, and non-military use of land within the 10-mile Zone and its approaches is under revocable licenses by the government to steamship companies and planters. The canal was built within a period of ten years, of which the first three were occupied with extensive preparations, of which the chief were sanitation and disease control within the Zone. This included provision of pure water supply to the Zone, including the towns of Colon and Panama; adequate sewage disposal, food supplies and living quarters; complete drainage and mosquito eradication over a belt much wider than the Zone, with eradication of yellow fever and malaria, and the control of all other transmissible diseases.

The canal was constructed by a commission, consisting of four army engineers, an army physician, one navy engineer and one civilian. Of these Colonel Goethals was made chief executive with supreme civil and military power in the Canal Zone. The task of sanitation, disease prevention and eradication and all medical supervision was not exceeded if equalled by any other department of the work, in its fundamental value for the success of the project. Disease had invariably defeated its human antagonist disastrously in the nearly 400 years of effort to connect these oceans. Due to the skill and executive ability of the army physician on the Canal Commission, utilizing to the full the knowledge and experience of tropical medicine won, in no small part, by American physicians, the sanitary foundation was laid on which the canal was built. It is no exaggeration to compare the human service and value of the Panama Canal with that of the Suez Canal. At Suez the total cost was under ninety millions of dollars. At

Panama nearly three hundred and sixty-seven millions were expended, not including cost of military defense. Tropical medical science paved the way for success, a medical exploit worthy to rank with that of Henry R. Carter and the Yellow Fever Commission, as shining lights in the world's progress toward disease control. The army physician, in whom were so admirably focussed the capabilities of modern medicine and American executive genius, was Major General William C. Gorgas, later surgeon-general of the United States Army.

The medical problems at Panama were met fully and efficiently. They consisted of (a) protection of the working force, which averaged 39,000 men, against local communicable diseases; (b) care of sick and injured, not only among employees, but in Panaman population and from adjacent countries; (c) quarantine to prevent introduction of communicable diseases from other countries; (d) quarantine to prevent passing on communicable diseases to other countries from this cross-roads and pathologic mixing pot of the Americas; (e) research on problems of practical importance in the Canal Zone and general investigations favored by the abundant clinical and pathologic material available. The greatest disease enemies were yellow fever and malaria. Mosquito control and even eradication, by drainage, clearing brush and screening of houses and patients, wiped out the former and reduced the latter to a minimum. Fears as to the sanitary effect of new transport facilities through the canal between the Atlantic and Pacific have not been realized. In fact the quarantine control has become a world model, has facilitated shipping and has been a powerful agent in cleaning up disease foci in the tropical Americas in general.

Caribbean Coast of South America

The Caribbean Sea washes the tropical shores of South America from Panama to the island of Trinidad, off the eastern coast of Venezuela. Colombia, from which Panama revolted in 1903, is backward socially and difficultly accessible topographically. Lying across the equator, its southern edge rests in the forested Amazonian watershed. North of this the tributaries of the Orinoco have their origin. Here the llanos have a two season climate, a heavy wet season and a drouth-like dry season, both with high temperature. From the Arctic bleakness of the Cordilleran heights, change of altitude alone is sufficient in practically the same latitudes, to produce the wet, hot climate of the Caribbean Coast and the Magdalena River valley. Cooling winds are cut off here by mountains. The rain and heat of the coast, with the marshes and jungle, make it extremely unhealthy. The population shows two features of special note. (1) About one third is made up of Negroes and Negro mixtures. (2) One tenth is classed as white and consists chiefly of the descendants of Spanish colonists. Climate and the lure of gold have sent them into the interior altitudes, where they are still found, nearly unchanged from their ancestors, isolated, and only with small port colonies in the lowlands to give a meager communication with Spain. A. J. Lamoureux says: "The isolation of these inland settlements has served to preserve the language, manners and physical characteristics of these early colonists with less variation than in any other Spanish-American state. They form an intelligent, high-spirited class of people; with all the defects and virtues of their ancestry." Politically, Colombia is much harassed, like her neighbors, by changing régimes. So-

cially, she suffers for lack of a fair educational system, in spite of the traditional atmosphere of culture at Bogota. Economically her chief wealth is still from her mines, though pastoral industries are of some importance in the interior, and fruit raising, stimulated by American requirements, is rapidly increasing in the lowlands.

The coast of Venezuela is humid but relatively cool, due to the trade winds. About four fifths of the country is contained in the system of the Orinoco River and here one found wide-spreading grass plains, with low forests and shrubbery in places, and a dry climate hotter than on the coast. As in Colombia there is a large Negro mixture in the population and about 79 per cent. of the total are mixed breeds of some type. The climate is generally healthy wherever the coast trade winds penetrate, very hot and enervating elsewhere, and disease hazards are as much due to poor sanitation as to climate. In colonial times the inland plains, the llanos, pastured huge herds whose disappearance with successive wars has left the country a desert. Settled politics will lead to an enormous development of these fertile plains.

Amazon and Orinoco Valleys

From the island of Trinidad eastward a large part of the South American coast is occupied by the great valleys of the Amazon and Orinoco rivers. The Orinoco basin is almost entirely comprehended in Venezuela. Between its mouth and the outlets of the Amazon in Brazil is a small coast district, including British, Dutch and French Guiana. The Guianas share in the general character of the Caribbean littoral. There is a wide rich alluvial zone 18 to 50 miles in width, leading back to low plateau country largely covered with heavy jungle and containing the famous gold deposits. This zone gives way in the hinterland to savannahs and grassy plains, which rise into mountains, some of which are heavily forested. These colonies are distinguished by their rivers, which are numerous, and, as is so frequent in the Orinoco and Amazon basins, have many inter-connections. Tuberculosis is especially prevalent because of primitive sanitary ideas, and malaria of course is wide-spread. Hurricanes and heavy storms are unknown. The character of the coast makes tidal waves impossible and earthquakes harmless. French Guiana (Cayenne) has long had a French penal settlement and has furnished a site of exile for political and other offenders.

The rich valley of the Orinoco has today fewer inhabitants than in the time of its discovery 400 years ago. Its chief settlement is Ciudad Bolivar, 373 miles from the mouth. Its forest- and jungle-covered upper reaches are to a considerable degree unexplored.

The great River Amazon has a drainage basin of 2,720,000 square miles, which covers two fifths of South America. For its lower 400 miles, up to the straits of Obidos, it is merely a deep ocean gulf. It seems to consist of long level stretches with short inclines having very slight fall. The huge flood rise of fifty feet or more each year leads to two peculiarities. (1) It furnishes sufficient head from the great tributaries such as the Madeira and Negro, to carry the vast quantity of water to the Atlantic in a heavy current, through a mouth 160 miles in actual width. (2) It results in the peculiar and characteristic phenomenon of a huge flood plain, several hundreds of thousands of square miles in area, which is rarely more than fifteen feet higher than low water level, and which is inundated and cut up into numerous islands with connecting canals, water-courses and even new river channels, forming a tremendously complex topography, and which was a chief obstacle to navigation and exploration. An example of the peculiar channel re-

lations of this river system is seen in the natural Casiquiare Canal, which connects the Rio Negro, the great northern tributary of the Amazon, by a broad waterway, elevated some 300 feet above sea-level, with the Orinoco. Its origin in the Orinoco is about 300 feet in width, and its mouth in the Rio Negro is 1,750 feet wide. It is a major wonder of the world, unique and almost unbelievable.

The combat between the Atlantic tides and the discharge of the Amazon at its mouth results in the great Pororoca, or bore, a wall of water five to twelve feet high which rushes over the sandy shores and half-submerged islands at a speed of ten to fifteen miles per hour. This explains why the huge load of silt is carried far to sea and the river forms no delta, rather yielding coast-line to the Atlantic. The Amazon can be considered a tremendous reservoir, into which empty fourteen large rivers and an innumerable number of smaller ones.

The chief settlements are Para, just south of the mouth; Manaos, at the junction of the Negro, and Iquitos, in Peru. Navigation is rapidly increasing with several commercial lines running regular schedules and numerous small and local steamers. The population of the basin is relatively very small. Conditions of flooding, tropical jungles over the lowlands, intolerable insect pests, equatorial heat and high incidence of malaria and numerous other diseases have thus far prevented colonization and even exploration. The great immediate obstacle to development is the lack of food supply. After 400 years, not above 25 square miles are under cultivation. The scattered areas of settlement and development on the distant mountain headwaters are practically inaccessible.

The tropical lowlands of South America are seen characteristically in the Amazon valley. Nowhere in the world is plant life more luxuriant or varied. Here is the native home of several rubber plants, cotton, potato, tomato, mandioca, pineapple, maize, cinchona, ipecac, coca, vegetable ivory, chocolate plant, Paraguayan tea. Palms are the outstanding feature of the vegetation, occurring in a great variety of forms. Bamboos and an endless variety of ferns combine to make a floral richness nowhere equalled. Bananas, coffee, sugarcane and oranges have been introduced and grow luxuriantly. The forests are rarely limited to few species, but everywhere show great diversity, beauty and commercial richness.

The wealth of the Amazon to-day lies solely in native forest products, chiefly rubber. The iniquities of rubber collection in the Amazonian forests, the cruelty and brutality with which the Indians have been treated and the enormous difficulties of climate, disease and transportation have been described elsewhere and can not be exaggerated. The collapse of the rubber market in 1915, with the introduction of cultivated East Indian rubber, forced the inhabitants to turn abruptly to fishing and the cultivation of manioc, cane, corn, tobacco and nuts. Since 1910 commercial development has been extensive. The Madeira-Mamoré railroad, 220 miles in length, has opened a huge virgin territory, radio and telegraph have reduced the isolation, and several thriving towns have developed outside of the principal ports of Para, Manaos and Iquitos. Imports are increasing and population is growing. Para has about 180,000; Manaos, 40,000; Iquitos, 8,000; Scuitarem, 5,000, and Obidos, 3,000. Of the million and a half inhabitants of the Amazon valley, not over 200,000 live outside of Brazil. In exploration special mention should be made of the expedition of the American Rubber Commission—financed by the United States Government, and including ex-

perts from Brazil, Peru and Bolivia. Surveys were made on thirty-seven major water courses, with analyses of soil, climate, topography and especially suitability for cultivation of rubber and sugar-cane. Modern explorations of great value were made by the Roosevelt Expedition in 1913–14, the Fleming Expedition in 1919 and the Rice Expedition in 1924, as well as numerous smaller and more limited expeditions. It must be remembered that huge areas of Amazonia are unexplored; that the Indians of the forests are largely unknown, even with the advanced policy of conciliation of the Brazilian government; that extreme heat, humidity and impenetrable jungle combine with the savagery of the natives to make exploration difficult; and that the problem of local food supply and maintaining a foothold against the jungle is nearly insurmountable at present. It is a country of strange and grotesque phenomena; of vampires, small poisonous snakes and large crushing reptiles; of cannibals and head hunters; of strange poisons, blow-guns, dwarfs, giants, white Indians; of plants having weird properties like the yaǵe, which is said to release the subconscious mind; of strange occult rites, terrible and bizarre, like those of juripuri; of unknown intoxicating drinks; of countless hordes of insect pests, mosquitoes, sand-flies, jiggers, biting flies and numerous others. Beriberi is naturally sequent to the prevailing native dietary, while malignant malaria and blackwater fever are forever lying in wait.

Among the great problems of tropical medicine is the question of the availability of Amazonia for civilized human culture. It comprises the largest fertile, nearly vacant and unexplored area in the world to-day. Its productivity and richness are practically inexhaustible. The obstacles to its development are the flood conditions, climate, insect life and overpowering jungle forest growth already noted. Development here means primarily agriculture. Agriculture will depend primarily on medical control of disease conditions. The problem of permanent white colonization is discussed elsewhere. Future human food supplies are of paramount importance for future civilization. What has scientific medicine to offer for the control and development of this tremendous, rich empire of the tropics, now virtually lying fallow?

Eastern South America

Outside the Amazon, the chief river of Brazil is the São Francisco, entering the Atlantic well south of Cape Rogue, after a course through hilly and low mountainous country. The water system entering the Atlantic through the Plata estuary includes the Uruguay which parallels the coast and bounds on the west Uruguay and the southernmost state of Brazil; and the Paraguay and Paraná Rivers, which communicate with headwaters of the Amazon in the Brazilian Andes of Malto Grosso, Goyaz and Minas Geraes. The upper courses of this system are in tropical country, gradually becoming continuous with the Amazon basin. The upper Paraguay winds sluggishly across wide grass-plains dotted with palms and occasional peaks. Huge areas of inland plain, like the Gran Chaco in northern Paraguay and Argentine, are wet and covered with heavy vegetation. Disease conditions and native population are similar to those on the Amazon.

In the tropical area of the east coast is found the great coffee port of Santos with an excellent deep harbor. The heavy vegetation, swamps and great heat and rainfall of Santos have made it an endemic home for malaria, rheumatism, dysenteries, smallpox, beriberi and many other diseases. Plague has appeared since 1900 also. Good drainage has now made the city itself fairly healthful, and conditions are improving with a general policy of sanitation and drainage. Fifty miles northwest of

Santos is the fine city of São Paulo, connected with its port of Santos by a double-track railway. São Paulo, the "Heart of Coffee-land," lies at two to three thousand feet elevation on an inland plain, part of the city, however, being along the unhealthy alluvial bed of the Tiete River. Except for this portion, its altitude gives it a bracing climate with hot sun temperatures. It is a rich city and decidedly healthy in spite of poor sanitation. Its population is about 650,000. About ten miles from the city is the governmental snake farm, the Instituto Butantan, of world-wide reputation, where experimental work and anti-venin manufacture are carried on together.

Rio de Janeiro needs no additional description. The fight against the mosquito, the measures of disease control, the harbor, unequalled in beauty and natural adaptability, make it justly famed. Here is found the splendid Oswaldo Cruz Institute, named for its founder, who eradicated yellow fever and plague from Rio and was the pioneer in the system of sanitation and medical control which is already making substantial inroads on the disease problems of the Brazilian tropics. One third of the expense of maintenance is borne by the government. It is a model of its kind and ranks among the world centers for study of tropical medicine. Rio, São Paulo and Santos are important and up-to-date medical centers and for the student of tropical medicine furnish remarkable illustrations of what scientific medicine can accomplish in a tropical climate, with a race blended between Latins, Indians and Negroes. The Negro finds his greatest opportunity in Brazil, and in every respect is on equal footing, according to his individual capacities. Italian immigration is an important and valuable factor. With the native wealth of the country, the unusual blend of tropically acclimated races with an infusion of northern blood and a vigorous sense of nationality and of scientific values, the future of Brazil as a great tropical power is absolutely unlimited and unvisionable.

Plateau and Mountain Belt

In the Andes are found the most tremendous mountains of the western hemisphere, culminating in Mount Aconcagua in Argentina, 23,080 feet in height. The western slope is abrupt and in South America apt to be barren and cool. The eastern slopes are more gradual and give rise to the huge system of rivers already described. Two points of medical interest are to be noted. (1) The peculiar isolation of certain valleys of the northwestern Andes, as in Colombia and near Lima, where Oroya fever and verruga are prevalent. (2) The remarkably fine climate in the upland plateau regions, where altitude, moderate rainfall and absence of excessive humidity, combined with hot sun temperatures, give an unusually fine physical environment. These regions are contiguous to and often easily accessible from the hot disease-infested coastal and river lowlands.

Pacific Coastal Plain

The Pacific coastal plain is narrow, averaging some forty miles in width. From about 30 degrees south latitude to Guayaquil, just below the equator in Ecuador, it is barren, in many places, sandy, dry and cooled by the Antarctic current. Short inconstant rivers cross at intervals, but the ancient irrigation systems have not been adequately replaced or extended. Development waits on irrigation. From Guayaquil to Panama, tropical vegetation is found, with its accompanying heat and humidity. This continues largely through Central America, where Salvador is especially noted for its large variety of native medicinal plants. In Mexico, the region of the Pacific calms, the so-called "horse latitudes," gives a hot dry climate merging virtually into a desert on

the low coasts of Sonora and Lower California. Many rivers cross this area but are not utilized for irrigation. This dry hot climate extends over the high plains and deserts of northwestern Mexico and includes the southern portion of the southwestern United States.

Medical Considerations

South America is preeminently the land where racial mixtures can be studied almost as in a laboratory. Already it has proved that color is no barrier to racial intermixture. There is no race problem in the southern continent in the sense of a color or race line drawn socially and politically. Mixed bloods always rank with the higher type, whether Indian or Negro. Of the entire habitable and productive earth, South America has relatively the lowest population. It is therefore the last reserve area into which humanity will pour by immigration for settlement and commercially for exploitation and productive development. Like Africa, South America looks to the east and is influenced intimately by Europe, especially France. German and Italian immigration is important and brings to racial mixtures valuable additions. Political instability, with the lethargy and passivity of the Indian population, militate strongly against adequate and continuous public health programs. Climatic effects and wide-spread disease conditions, such as hookworm, venereal, tuberculous and malarial infections, have a definite influence in reducing initiative and interfering with development of a public conscience. The three elements which especially tend to make for backward health conditions are (1) the racial character of the population in the various countries of the American tropical zone, (2) true climatic factors, and (3) incidence of chronic debilitating diseases and defective nutrition. It is a question as to how much political instability is also secondary to these factors. As so often in human affairs, medical conditions in the broad sense are fundamental for human advancement.

VIRUS DISEASES OF PLANTS

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ABOUT 1868, a remarkable plant, which was said to have originated in the West Indies, appeared on the European markets. It belonged to the genus *Abutilon* and was remarkable for two reasons. First, it had very beautiful, variegated foliage; and second, this character was not transmitted through the seeds, which produced plants with green foliage. But these beautiful variegations could be transmitted by budding or grafting scions from variegated plants to green plants. Furthermore, the green shoots of various other Malvaceous plants which had been grafted with variegated scions frequently developed foliage of the same kind, indicating that this character was transmitted in some unknown manner through the sap from the variegated scion into the green branch. These ornamental plants became very popular and were sold under the names of "variegated maples" and "Chinese bell flowers," but no one suspected that the mottlings were symptoms of a disease and that this was the first important step in the study of a group of maladies which are now known as "virus diseases."

This was not the first virus disease to attract attention, but the fact that it could be perpetuated by grafting and not by seeds marks an epoch in the history of these maladies. Many irregularities in plant growths which we now recognize as virus diseases had been noted for centuries. One of the most interesting of these is a disease of tulips, known as "breaking," which causes the infected flowers to develop beautiful variegations in colors. The earliest records of this disease are pictures of about 1640 to 1650. It was recognized, many years ago, that these variegated tulips were less vigorous than the ordinary plants, and it was assumed that this beauty was the result of the final efforts of the plants to express their gratitude for the care and attention which they had received from the growers. "The Gardener's Dictionary" (1758) contains a very interesting discussion on this subject which reads as follows:

> This alternation in the Colour of thefe Flowers may be feen long before they are blown, for all the green Leaves of the Plant will appear of a fainter Colour, and feem to be ftriped with white, or of a brownifh Colour, which is a plain Proof, that the Juices of the whole Plant are altered, or, at Leaft, the Veffels through which the Juice is ftrained; fo that hereby Particles of a different Figure are capable of paffing through them, which when entered into the Petals of the Flower, reflect the Rays of Light in a different Manner, which occafions the Variety we fee in the Colours of Flowers (but this is more fully explained in the Article VEGETATION; which fee). This breaking of the Colours in Flowers proceeds from Weaknefs, or at leaft is the Caufe of Weaknefs in Plants; for it is obfervable that after Tulips are broken into fine Stripes, they never grow fo tall as before, nor are the Stems, Leaves, or Flowers, fo large, and it is the fame in all other variegated Plants and Flowers whatever, which are alfo much tenderer than they were before they were ftriped; fo that many Sorts of exotic Plants, which by Accident became variegated in their Leaves, are often rendered fo tender, as not to be preferved without much more Care, though indeed the ftriping of Tulips doth never occafion fo great Weaknefs in them as to render them very tender. The greatest Effect it hath on them, is in leffening their Growth, caufing fome (which, while they continue in their original plain Colours, did rife near three Feet in Height) to advance little more than two after their Colours were altered; and the more beautifully their Stripes appear, the fhorter will be their Stems, and the weaker their Flowers.

Within the last few years, it has been demonstrated that the beautiful variegations in "broken tulips," which have attracted attention for so many years, are the symptoms of a virus disease.

A disease, similar in character, which has been known in tobacco for many years, was finally recognized as injurious and was the subject of an important paper (1886) by Mayer, who gave it the name of "mosaikkrankheit." The equivalent—mosaic—has been very generally accepted for a number of mottling diseases by the English and American students. This was the first important scientific paper on a virus disease in plants and may be looked upon as the starting point in our studies of this subject. This was followed two years later by an extensive bulletin on peach yellows by the late Dr. Erwin F. Smith. This disease had been known in America since 1791 and had been attributed to many causes, but the true cause was not demonstrated until many years later. Although Dr. Smith did not learn the cause of this disease, he learned many important facts which have been of great value to later students.

Extensive studies since the beginning of the present century have called our attention to mosaic diseases of many species of plants, and a large number of plant diseases, such as little peach, peach rosette, ring spot of tobacco, curly top of sugar beets, bunchy top of bananas, etc., all of which possess certain characters in common. Recent studies have resulted in their being classified in one common group known as "virus diseases."

Many of these diseases are the causes of very heavy losses in our agricultural crops. A disease of potatoes, which was known in England by the name of "curl" as early as 1757, was recognized as an important factor in the reduction of the crops. We now recognize several virus diseases of potatoes which cause losses. The virus diseases of sugar-cane, sugar beets, peaches, potatoes, tomatoes and tobacco are well-known causes of heavy losses, both in actual crop production and in the use of methods for their control.

In 1892 Iwanowski reported a discovery which was of much greater importance than he realized, a discovery which was destined to revolutionize the study of many diseases of both plants and animals. He found that the active agent which caused the mosaic of tobacco would pass through a filter that was fine enough to remove bacteria. Six years later (1898), Beijerinck confirmed the work of Iwanowski. In this same year, Loeffler and Foosch in Germany discovered that the active agent of the foot and mouth disease would pass through a porcelain filter. This was followed by the discovery that the active agents of many diseases of both plants and animals would pass through bacterial filters and retain the power of transmitting disease. Eventually these maladies became known as filterable "virus diseases" and are now recognized as among the most important branches of plant and animal diseases. Many of these filterable virus diseases have been recognized and the symptoms described. A very large number of trained men and women have been and are employed in the studies of these maladies and an extensive literature has been published.

The causal agents of these diseases have attracted the attention of research students from the first. Mayer believed that the mosaic of tobacco was caused by bacteria, and this theory was supported by Iwanowski and others and has some adherents at the present time. This was a very reasonable theory, because the new branch of science known as bacteriology, which had developed as a result of the work of Pasteur, had explained so many phenomena which were

not understood previously. Mayer believed that the bacteria were transmitted in the soil, and Iwanowski believed that at certain periods in their development they were small enough to pass through a bacterial filter.

Beijerinck (1898) rejected the bacterial theory and advanced the theory that the active agent was a living fluid, which was parasitic in the cells of the host plant, and gave it the name "*contagium vivum fluidum.*" This was followed very quickly by the enzyme theory, which was advanced in 1899 by Woods in America and by Heintzel in Europe, working independently. Woods published three papers in which he expressed the belief that the mosaic disease of tobacco and some other plants resulted from an excessive accumulation of oxidizing enzymes, which prevented the normal production of chlorophyll and caused a partial starvation of the plants. He was probably influenced by the studies on enzymes which were attracting so much attention and by the knowledge of the effects of oxidation on chlorophyll. This theory was very favorably received by a large number of workers and still has a considerable number of supporters.

The next important theory was that protozoa were the causal agents, based on the fact that protozoa-like bodies have been seen in the cells of many plants infected with virus diseases. Iwanowski (1903)[1] was the first to report these bodies. He found them in the cells of mosaic tobacco plants but believed them to be the results of the disease rather than the cause. In 1910, Lyon, of Hawaii, reported plasmodia-like bodies in the cells of sugar-cane infected by Fiji disease, which was not at that time included in the virus diseases. In 1921, Kunkel reported the finding of intra-cellular or X-bodies in the cells of mosaic corn and suggested that they might be the cause of the disease. These bodies were strikingly similar to those described for tobacco by Iwanowski in 1903. The work of Kunkel was followed by the finding of similar bodies in the cells of many plants infected with virus diseases. Many students believed that these bodies were the causal agents of these diseases, while others believed that they were the products of the diseased cells.

This was followed by the discovery of flagellate-like bodies in the cells of mosaic plants, and in December, 1922, Nelson read a paper before the American Phytopathological Society in which he reported the finding of bodies which he believed to be flagellates in the fibrovascular bundles of several species of plants that were infected with virus diseases. Some confirmatory and much negative evidence has been advanced by workers in different parts of the world since that time. This was followed by the plasmodial theory, which was advanced by Jones, but which has not received much support.

Many other theories have been advanced from time to time, such as character of the soil, insects and other agencies. So much attention has been given to the studies of soils and fertilizers that this theory offered a most fertile field for unscrupulous commercial organizations and "quacks" who had wonderful discoveries and patent processes for the cure of these diseases.

The filterable virus theory, which is the one most generally accepted at this time, can not be attributed to any one student of the subject. The name "virus" was used by many workers who were advocates of other theories and long before there was any definite grouping of these diseases as a result of the recognition of common characters. The original meaning of the word was liquid poison, but it was later applied

[1] In this same year Negri reported the finding of small bodies in the brain cells of animals attacked with rabies.

to the material used for vaccination for the prevention of smallpox and still later to designate the material used for the prevention of other diseases. It gradually came into its present use between 1915 and 1920 as a name for the active agents of certain diseases, most of which are known to pass through bacterial filters and retain the power to produce the diseases when inoculated into plants of the same species (and sometimes other species) from which they were obtained. This definition is not entirely correct, because it is well known that some bacteria will pass through a filter and because it is also well known that some of the virus diseases have not been transmitted by inoculation with either filtered or unfiltered juices of plants, but have been transmitted by grafting or budding. But these diseases have so many characters in common that we believe that we are justified in classifying them in the same general group.

The properties of the active agents may be described as follows: (1) They are infectious; (2) they are present in nearly all parts of the infected plants, but are rarely transmitted through the seeds; (3) they increase in quantity within the plants; (4) in most cases they will pass through filters that retain bacteria; (5) very small quantities and very great dilutions of juices from infected plants will transmit many of these diseases; (6) they are influenced by changes in temperature and can not live beyond certain ranges; (7) they are modified and killed by certain chemicals; (8) some of them become attenuated as a result of transmission through resistant plants; (9) they are influenced to some extent by light; (10) a very few workers claim to have grown them in cultures.

The transmission of these diseases from plant to plant is a factor that has attracted the attention of the students from the very first. The variegations of *Abutilon thompsoni* (1868) were transmitted by grafting long before this character was recognized as a symptom of disease. Smith (1888) reported that peach yellows could be transmitted by budding, and since that time it has been demonstrated that a very large number of these diseases can be transmitted by this method. Mayer (1886) reported that the mosaic of tobacco could be produced by inoculating a healthy plant with the juice from a diseased plant. Later workers believed this disease could be transmitted by mere contact between diseased and healthy plants or by merely touching a diseased and then a healthy plant, and it was demonstrated that the field laborers were frequently responsible for its spread in the fields. In 1917 Allard reported that the common tobacco mosaic of America could not be transmitted in this manner unless the healthy plant had been injured, although a very slight breaking of the plant hairs was sufficient for the entrance of the active agent. It is now known that many of these diseases can be transmitted by the inoculation of healthy plants with the juices from diseased plants and that field laborers are responsible for the spread of some of them. Transmission by vegetative parts, such as tubers, bulbs, roots and cuttings, is recognized in a large number of species of plants. Transmission by pollen has not been demonstrated, but transmission by seeds, although not general, has been demonstrated for a number of plants.

One of the most remarkable, interesting and important phenomena of these diseases is the transmission by means of insects. Woods called attention to aphids which were associated with the Bermuda lily disease in 1897 and to stigmonose of carnations in 1900, but it was not known at that time that these diseases had anything in common with

what are now known as virus diseases. The first demonstration of a virus disease by means of an insect was the curly top of sugar beet by the leaf hopper (*Eutetix tenella*) in 1906. No one at that time knew that curly top was a malady with properties more or less in common with many other diseases that are now grouped under the common name of "filterable virus diseases," and Ball, who performed the first experiment, believed that curly top was caused by the insects. In 1910, Shaw reported the results of experiments which demonstrated that the disease could be produced by leaf-hoppers which had fed on curly top beets in the Southwest and then been carried to Washington, D. C., where they were put into cages with healthy plants. He did not succeed in producing the disease in any other manner. The work of these two men led to extensive studies by other workers, who have demonstrated during the last two decades that a very large number of these diseases are carried from plant to plant by insects.

The virus diseases of plants are now recognized as constituting one of the most important fields of study in plant growth and one of the most important branches of plant pathology.

MACRO-CEPHALISM

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EDMUND SPENSER, in "The Ruines of Time," tells the reader to

> Looke backe, who list, unto the former ages,
> And call to count what is of them become:

and asks, like many another poet, the question:

> Where be those learned wits and antique Sages,
> Which of all wisedome knew the perfect somme?

The answer is, of course, that they have taken a back seat; the seats of the mighty being now filled by the "great scientist" and the "big business man."

The substitution is both reasonable and just. In former ages, when there was an aristocracy of birth, there was naturally also an aristocracy of learning; men had leisure to think, men had leisure to learn, men had leisure to live, men had leisure even to dream. Possessions, if the "antique Sages" had them, were a means for enlarging and beautifying life, for expanding the realm of the spirit and extending the reaches of learning. But with the rise of the middle class with its "philosophy of possessions as a sign of worth," that what a man has, he is; the doctrine that possessions "are nine points of the law" and ten points of the remainder of life; with all these things came the rise of an aristocracy, so-called, of wealth, and the decadence of the sages who, while they had a knowledge of possessions and their power, preferred the wisdom of simplicity and its worth.

In a way this reversal of society makes for simplification, not of life but of classification. What a man has, he is; and what he has follows the income tax returns. So that a man is placed, and, barring death and "depressions," remains fixed. Then the privileges, insignia and regalia of his social class are known, so that, as a self-appointed authority on social usage has declared, "no man with less than $5,000 a year may carry a walking stick," and, possibly, not less than $10,000 a year will confer the privilege of wearing spats.

These details, however, are of less interest and importance than the general idea of the replacement of the humanist

by the scientist. This replacement has been, of course, an evolution, not a revolution; and in this connection it is well to emphasize that evolution is not necessarily good any more than revolution is necessarily evil. The displaced humanist, whether Latinist or Hellenist, at the height of his renown was, strange as it may sound, human. He bowed down before the gods of necessity in order to live for better things, but never in real worship. His successor, the scientist, also is human and bows down before the gods of riches in that sincerest worship which expects as a return to share in the gifts of his gods, though it is true so far that, like Lazarus, he has had to be content with the crumbs that fall from the rich man's table.

There was a time when the scientist was modest. Indeed, it is only within the most recent years that he has attained to his present place, the footstools before the thrones of the truly great and wealthy, and his success illustrates a curious phase of evolution in which a new disease, bacterium or bug attacks a species, of which those only survive who are fit.

The disease, which may be called "macro-cephalism," had for some time been prevalent in big-business circles. Its incidence was wide-spread but the death rate small. At about the time of the world war the contagion spread to the chemists who, by their researches into the deadly instruments of war, ammunition, poison gas, etc., had been thrown in contact with the makers of such things, thus helping to intensify the horror of war and to enrich themselves. Amongst the chemists after the war the disease became much less virulent, partly because the unfit had succumbed, partly because an attack of the disease renders one partially immune to further attacks.

In the meantime the chemist and physicist, finding they had many things in common, had begun to fraternize and to banquet each other after the manner of the Fox and the Crane. Thus the contagion spread to the physicists, and amongst them the epidemic is now raging at its height. The great private and corporate industrial laboratories, established *ad majorem*—is it *scientiae* or *pecuniae gloriam?*—over whose portals is written in letters of gold two cubits tall the magic word "Service," have become like hospitals where all the patients have the same disease, and even the laboratories of our institutions of learning contain cases, more than sporadic, of macro-cephalism.

The most interesting and remarkable symptom of macro-cephalism is that it causes the patient to know—or to think he knows—everything. This symptom seems to be much more prevalent among the physicists than among the chemists, in this respect putting them almost on a par with the big business cases where the symptom is universal. Under the influence of the disease the patient will undertake the solution of every problem of science, economics, politics or finance; he will fix the place, if it have any place, of art in the social life of man; he will produce the perfect and universal system of morals; he will even reconcile science and religion, making of "science itself a philosophy of life and a justification of religion, as though the nescience of the physicist was the certainty of the theologian." All of which would be very comforting to mankind were it not that all the solutions, all the reconciliations are infused with the vagueness, the vacuity, of a mind working under the influence of disease.

Efforts to treat the disease have met with little success. Dr. Astronomy, with his mysticism, and Dr. Biology, with his materialism, have so far succeeded only in catching the disease themselves—in a somewhat mild form, since their opportunities for service are rather limited. The only treatment in any degree help-

ful has been that of the mathematician, and this has been vitiated by the fact that it starts from an incorrect diagnosis and is almost exclusively based upon empiricism. It is also doubtful if the mathematician, as a specialist, has not been disposed to increase his fees by prolonging the cure. His principle seems to be "more of the same." If three dimensions won't do, give the patient four, or five, or any old number.3½7 Also he has experimented by varying the shape, or curvature, of the medicine goblet in which the dimensions are immersed. Indeed, with the help of the astronomer, he once made a sort of rubber goblet which expanded and contracted into the weirdest shapes as the patient swallowed his dimensions. The mathematician, except in rare cases, seems to be immune to macro-cephalism, but when he does get it he gets it bad.[1]

But the allegory may now be left to bask on the banks of the Nile, for

> The time has come
> To talk of many things:
> Of shoes—and ships—and sealing wax—
> Of cabbages—and kings—

to talk, not as the "antique sages" did, of how many angels can dance on the point of a needle, but of how many electrons can jazz around a proton. But, after all, are not the two questions much the same? To the medieval philosophers, angels and devils were as real, as actual, as electrons and protons to the modern scientist, or as solid atoms and the ether to the scientists of Victorian days, or as gravity and force to the Newtonians. After all, these are but names given to things unseen and unknown except by what they do, by their effects. "Hast thou seen him ever anywhere," the electron, the angel? "Ah, no," replies the scientist, "but I have seen his illuminated path." "Ah, no," replies the poet, "but his 'trailing clouds of glory' I have seen." Oh, names, names! Calling them angels and devils, the medieval philosopher thinks he understands and "explains"; calling them electrons and protons, the modern scientist "explains" and understands in quite the same way. This is no true knowledge, for only "by their fruits ye shall know them," and if names are the fruits of knowledge surely Beelzebub is as crystal clear as Para-ethoxy-phenyl-thio-carbamide, and no more terrifying. As Alice said of Jabberwocky, "It seems very pretty, but it's *rather* hard to understand!—Somehow it seems to fill my head with ideas—only I don't exactly know what they are!"

There may be some permanent, ultimate reality back of, beyond, man's knowledge. If so it is unknown to man and probably will be forever unknown. Reality to man is what he knows now and here. There was a time when the earth was—I do not say seemed—the cosmic center around which sun, moon, planets and stars revolved in crystalline spheres. There was a time when the sun was—I do not say seemed—the center around which the planets moved in circles and epicycles. To-day the planets move around the sun in ellipses, in a space of five dimensions, of which only four are in actual use, as part of a universe contracting and expanding like a huge, globular jelly-fish. To-morrow —? As Milton says:

> He his fabric of the heav'ns
> Hath left to their disputes, perhaps to move
> His laughter at their quaint opinions wide.
> Hereafter, when they come to model heav'n
> And calculate the stars, how they will wield
> The mighty frame, how build, unbuild, contrive,
> To save appearances.

However modeled, however wielded, the heavens, the earth and the fulness

[1] The latest bulletin from the sick room states that a new treatment has been begun by Dr. Mathematicus. Instead of an infusion of electrons and dimensions in space, an elixir of "The *psi* function of wave-mechanics" is being administered. The patient is doing as well as could be expected.

thereof thus got will be real. Reality for man is that which he conceives, invents, "now and here," so that the boasted progress of science is but a substitution; a substitution of new lamps for old. The new lamps are brighter and give more light, perhaps, but they lack the wonder-working power of the old. The new lamps guide us on our daily path, but the old lamps revealed and made real to us all the treasures and marvels of the universe save one—the rukh's egg of omnipotence.

There may be dissenting voices to what has been written, but to the assertion that, here and now, the world in which mankind lives is the world of *possessions*, there will be no dissent. There was a time when the scientist, like the humanist, lived in a world of his own; a world in which he strove for self-development through knowledge; but now he strives for aggrandizement through power. Then he studied nature in search of beauty and truth. Now he studies the stock market in search of possessions. He has pulled science down from her altars to make her the servant of industrial expansion. He has become the right hand of the industrial body and hopes to become its head by "boring from within." He will probably succeed. He has learned the game. He has learned the value of advertisement and publicity, and makes full use of them. He is forming "fellowships of super-scholars," intellectual super-chambers of commerce to guard the interests of his class. He is devising ways to "attract in large numbers to the academic life men of independent means," not an unheard of effort in the educational world but—try and do it against the current of scientists flowing into industry. He will succeed, but like the investors of 1929 he forgets that there is a debit side to the ledger. He will succeed, but he will lose what Lord Dunsany calls "that elusive thing that lies just beyond the limit to which Science has penetrated," and will feel (investors of '29 also please note) "all the bleak emptiness there is in the world when mystery has left it." But one thing he will not lose. He will still be one in the great fellowship of the macro-cephalists.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

URANIUM AS THE EARTH'S CLOCK

By Dr. ALOIS F. KOVARIK

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MAN has an inborn desire to learn. If this were not true, progress would indeed be slow. When an archeologist discovers some old grave, man the scientist and man the layman show great interest in the age of the grave, in the individual buried there and in the social conditions that may have existed when the occupant of the grave still was alive. For identical reasons man is interested in the age of our earth, on which he considers himself as the supreme master among the living things.

Now, when we talk of the age of anything, we must bear in mind two important things: the first is the starting point from which we measure the age and the second is the clock employed in the measurement of the time. For example, the age of an individual is usually measured from the date of his birth and the usual unit of time is the year. The conception of the year by some people is merely the time that elapses from any date on the calendar to the same date on the next new calendar; while to others it represents the time for the earth to complete its elliptic path around the sun. In either case the year represents the time that elapsed during the performance of a series of events and the next year will represent the time that will elapse in the performance of the same events.

Galileo, the great Italian physicist whose work placed science on an experimental basis, measured time in his experiments in two ways. In one method he utilized the periodic swing of a pendulum, which later in the hands of a Dutch physicist, Huygens, became the basis of construction of our pendulum clocks. In the other method, Galileo used a large tank of water and allowed the water to flow out through a small faucet into a container. If a cup of water was so obtained it measured a definite time for that water to flow out, while two cups required twice as long a time and half a cup only one half the time. Therefore, by weighing the water so obtained during an experiment, he had a measure of the time that elapsed. This was Galileo's "clock," which served him admirably to discover some of the fundamental laws of mechanics.

Consequently, if we are concerned with the age of the earth we must first of all define our starting point and then look for some series of events which in their repetition will give us a "clock" to measure the time.

To the Latin poet and philosopher, Lucretius, the world began when poets began writing poems about their heroes; to the theologians the biblical world begins with the first generation recorded in the Old Testament and their unit of time is the generation of mankind. On the other hand, the biologist is interested in the time when life began on the earth; the seaman is interested in the time when oceans began; the geologist is interested to know when the first crust of earth was formed and the age of any subsequent formation; while the astronomer thinks of the probable separation of the earth from the sun, and the cosmologist philosophizes about the origin of the universe.

Certainly, all these so-called "worlds"

are interesting, but it must be clear to every one who gives them a little thought that their "ages" are very different. We shall concern ourselves with the geologist's problem and shall consider the "geologic age," *i.e.*, the time elapsed since the beginning of the oldest formation on the surface of the earth, and incidentally we shall give some thought to the age of any formation.

When any of these geological formations were produced, various minerals were also formed in them. These primary minerals are therefore as old as the respective formations in which they are found. Some of these minerals contain radium and other radioactive elements.

Radium, to most of us, is the best-known radioactive element. It possesses the fundamentally distinctive property of not remaining radium forever, but is, in fact, changing right before our eyes into another element, which likewise changes, and this goes on until the last radioactive element of this series, known as polonium, changes into a type of lead which is not radioactive, *i.e.*, it does not change.

Like any other element, radium is made up of atoms, and it is, of course, the atoms which change. An atom of any element is in fact a complicated arrangement of electrical particles and of energy; but in a radioactive atom the arrangement does not possess permanent equilibrium. Due to causes which as yet are not known to us from experiment, the equilibrium of a radioactive atom becomes at some time unstable, and then an explosion occurs during which either an electron or an alpha-particle (the latter, in fact, being the nucleus of a helium atom) is ejected and with it is also ejected some of the energy. What is left of the atom becomes reconstructed into an atom of the next element following it in the series.

Atoms of radium eject alpha particles when they disintegrate. By studying these ejected particles and the various effects they produce, we learn various things about these atoms. We find, for example, that in the case of radium four atoms out of every ten thousand radium atoms undergo this change every year. The statement that 4 radium atoms out of every 10,000 radium atoms cease to exist as radium atoms every year, characterizes the radioactive element radium. When the statement of the law of radioactive disintegration is put in this form, probably, some of you will recall a similar law, namely, the one in connection with life statistics. There we find that approximately 15 people out of every thousand, considering all ages, die every year. In both cases we are stating that a certain percentage of the existing individuals (radium atoms or people) cease to exist every year. In the case of the people, imagine that births suddenly cease and that 15 out of every 1,000 of the 2 billions of the earth's inhabitants die every year. Then 30 million will die the first year and 1,970 million will be left. During the second year about 29½ million will die, leaving 1,940½ million to begin the third year, and so on, the number dying each year decreasing because this number is a definite percentage of those living, which number, however, is continually decreasing.

Now suppose a cemetery is started for these dead at the time the births ceased. If, after some years, but within the period that some people are still living, a stranger visited our earth and observed the number buried in the cemetery, observed the census of the living for that particular year and also the percentage of the living that died in a given time, could this stranger calculate how old the cemetery was?

If the same number died every year calculation would be one of simple arithmetic. Since it is the percentage of those living that remains constant, by our hypothesis, the problem is not so simple; yet it is only slightly more difficult.

Now, this is exactly the problem we have when we consider the age of the mineral, which age will also be the age of the geological formation in which the mineral is found.

We must now note, however, that a radium atom was formed from a uranium atom which has undergone several changes similar to that which the radium atom itself undergoes. Uranium also has a characteristic percentage representing the death rate of the uranium atoms. Stated in the same language as for the radium atoms or for the earth's inhabitants, it is that 15 uranium atoms out of every one hundred thousand million of uranium atoms disintegrate every year. Each one of these atoms disintegrating becomes at some time a radium atom and at some later time an atom of lead. The atoms of lead do not change and they may be looked upon as the "dead" ready for the cemetery.

Consequently, our radioactive mineral contains not only the uranium atoms which have not yet changed but also the dead atoms of uranium which are the atoms of lead. When a chemist analyzes the mineral and finds the amount of uranium and the amount of lead, he has really taken a census of the living and dead uranium atoms. If also we count the number of uranium atoms which died as such in a given amount of uranium by counting the number of signals sent out by these dying atoms—namely, the alpha particles ejected, there being one alpha particle for each atom dying—we obtain the percentage changing per year required to be used as our "clock" in measuring the time, the total time depending on this measure and on the number of the dead uranium-radium atoms and on the number of the still living uranium atoms.

In this method of deducing the age of minerals we use the "percentage" of the uranium atoms existing at any time as the number disintegrating per year at that particular time as the clock registering the time. The accumulated lead has to be measured off by this clock, which then gives us the number of years during which the accumulation continued: *i.e.*, during which this clock was running—and this is the age of the mineral and of the formation from which the mineral came. This method is due to the late Bertram Borden Boltwood, of Yale.

Some radioactive minerals—in fact, most of them—contain thorium as well as uranium and radium. The thorium atoms undergo similar changes, having their own characteristic percentage changing per year and ultimately leaving the final atoms—the dead atoms of thorium—as atoms of another type of lead, each of which differs from the one obtained from the uranium in that its atomic weight is different. This atomic weight is a symbol by which one tells one type of lead atom from another. If in our cemetery we also buried, say dogs, and labelled the graves of humans by crosses and of dogs by columns, we could tell these apart and count them separately. The different atomic weights of these lead atoms make it likewise possible to get these different lead atoms counted separately.

When we apply our knowledge to the data obtained from the analysis of a uranium-radium mineral from Sinyaya Pala in Carelia, Russia, we deduce the age of the oldest radioactive mineral known and it comes out to be 1,852 million years. We can then say that the earth's crust is at least 1,852 million years old. Some minerals in Norway are found to give about 850 million years for their age, and therefore the formations in Norway are younger or of a later period.

WHAT BLOOD TELLS

By Dr. M. H. JACOBS

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In the old romances, when a man sold his soul to the powers of darkness, it was customary for him to sign the agreement with his blood. In this way, presumably, he left upon the paper something that was a characteristic part of himself, and so made the contract more binding. This more or less instinctive belief that an individual is in some special way represented by his blood has found scientific support in recent years. By means of methods that have been developed chiefly since the beginning of the present century, a small sample of blood may now be made to yield a surprising amount of information about the individual from which it came.

The first thing that such a sample of blood tells is the kind of animal that supplied it. To the unaided human eye there are no very distinct differences between the bloods of the thirty or forty thousand known kinds of vertebrate animals. Nevertheless, it is possible not only to show that each of these kinds of blood is different from every other kind, but, if necessary, to identify a given sample. For this purpose a few drops are usually sufficient—indeed, sometimes a mere dried blood stain may be employed. This latter possibility has at times been put to practical use in murder trials. Suppose, for example, that in such a trial a bloodstained ax is offered as evidence. The prosecution claims that the blood is of human origin; the defense contends that it is that of a chicken. There should be no very serious difficulty in such a case in identifying the blood and possibly in this way in determining the outcome of the trial.

Some of the most delicate and precise methods of identifying blood require the use, not of ordinary chemical reagents, but of blood itself. For example, a rabbit by the proper technique is given several doses of human blood. Its own blood is changed by this treatment in such a way that it now reacts strongly against human blood. A serum obtained from it, among other things, gives in a test-tube a whitish precipitate with the proteins of human blood—even if these have been merely extracted from a dried blood stain. With the proteins of chicken blood, on the other hand, it gives little or no reaction. An anti-chicken serum shows exactly the opposite behavior, reacting with chicken but not with human blood. This is the so-called precipitin reaction.

An even more dramatic method of identifying blood is by a test which succeeds best with the guinea pig. A normal guinea pig is ordinarily not harmed by the introduction into its circulation of blood from some other animal, provided that this is not done more than once. But if a preliminary sensitizing dose of a minute amount of, say, human blood is given in the proper way to such an animal, this particular kind of blood becomes a deadly poison to the sensitized animal and a subsequent dose of even a fraction of a drop may kill it within a few minutes. Other kinds of blood than that used for sensitization, however, remain relatively harmless.

When fresh blood is available for examination, specific differences may sometimes be detected by extremely simple methods. For example, the blood of the horse on standing rather quickly separates into an upper colorless and a lower red layer. The blood of the ox, which is otherwise identical in appearance, generally remains red throughout. The blood of the mouse can be distinguished

from that of a large number of other animals by the fact that, when a drop of it is added at room temperature to a 3.7 per cent. solution of a substance called erythritol, a transparent red solution is obtained in about five minutes. The other kinds of blood give turbid suspensions, which usually require hours to become clear. The blood of the chicken differs very strikingly from that of the duck and the pigeon in the slowness with which it forms a clear solution in water. Many other examples of this sort might be mentioned, though they are as yet of little practical importance.

Blood not only tells us about differences between animals but about resemblances. For example, the precipitin reaction is specific in the sense that it is most intense with the blood of some particular kind of animal. But it occurs to a lesser extent with the blood of other related animals. Thus, an anti-dog serum gives the best reaction with dog's blood, but a fairly good one with the blood of the fox, a much less marked one with the blood of the cat and so on. One of the most interesting tests of blood relationship of this sort was made some years ago by Friedenthal, who was able to demonstrate by the precipitin reaction a relationship between the blood of a living elephant and that of a Siberian mammoth that had been dead and preserved in a frozen condition for perhaps 25,000 years. In this connection it is of interest to note that the blood of the higher apes, such as the chimpanzee, for example, shows a very strong resemblance to that of man—stronger even than it does to that of the lower monkeys. In view of this blood-similarity it is not surprising that the higher apes are subject to almost exactly the same diseases as man.

Blood not only tells about differences and relationships between species, but it is beginning to do so in the case of individuals belonging to the same species. Some years ago Todd and White were able to prepare sera by means of which the blood of individual cattle could be distinguished from that of dozens of other cattle. Todd has recently extended this work to chickens and again has found it possible by a somewhat different method to identify individual chickens by their blood. In the case of brothers and sisters the bloods are very similar, but even here by the use of the most refined methods slight differences can be detected. Results such as these lead us to ask whether it will ever be possible to identify John Smith by his blood as he now can be identified by his finger prints. There is no theoretical reason for doubting that this may some day be possible, though certain practical difficulties have so far prevented much progress in this direction with human blood.

A question that is frequently asked is whether a sample of human blood can tell us the race of the person from which it came. The answer is that in most individual cases this is not yet possible, though some information may at times be obtained. We can, for example, in many cases say with a high degree of probability that a given sample of blood could not have come from a pure-blooded American Indian. It happens that in this race three of the four well-known blood groups, for which tests are made before blood transfusions, seem either to be absent or very rare, and consequently blood of any of these three types must, as a rule, come from persons belonging to other races.

Where large numbers of individuals are involved, so that statistical methods can be employed, the case becomes more favorable. For example, suppose that in India a series of 500 samples of blood were collected from native Hindus and a similar series from Englishmen living in the same region. It would be extremely easy to decide by the proportions of the different blood groups which set represented the English and which the

Hindu blood. Verzár and Weszeczky were able to demonstrate in this way very clear racial differences between the Hungarian, German and Gypsy elements of the population of Hungary, even after several hundred years of residence in the same region.

Finally, we may consider briefly what blood tells about the relationship of human individuals. In certain cases, where the relationship is that of parent to child, blood is capable of telling a great deal. The common blood groups are inherited according to definite laws which frequently make it possible to say that a given child could not belong to certain parents. An application of this principle received a great deal of publicity a few years ago. It happened that in a hospital in Chicago two new-born infants were accidentally exchanged, and a dispute arose as to which child belonged to which parents. The case fortunately proved to be one that could be definitely settled by a study of the blood groups of the six individuals involved—I say fortunately, because a certain proportion of such cases is as yet incapable of solution. Until a few years ago the proportion of favorable cases in an average American population, according to Wiener, was only about one in four, but the recent discovery by Landsteiner and Levine of the so-called M and N factors in human blood has increased this proportion to about two in three.

The celebrated case that Solomon was called upon to decide was a much more difficult one, because it involved only three individuals instead of six. The chance of settling a case of this sort satisfactorily by a blood examination of one child and two women would until recently have been only about one in twenty, and even at present less than one in five—so Solomon was perhaps wise in not depending upon a blood test.

It is evident from what has been said that blood does not yet tell us all that we might wish to ask of it. We must remember, however, that studies of this sort have been in progress for not more than about a third of a century. Only a very rash prophet would try to predict what blood will be able to tell a hundred or two hundred years from now.

HEART DISEASE OF MIDDLE LIFE

By Dr. C. S. WILLIAMSON

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It is becoming a matter of common knowledge that of the diseases which are taking off men and women in middle life heart disease holds a foremost place. The usual lay conception of heart disease is very far removed from the actual state of affairs, and so it is proposed here to discuss the heart conditions of middle life. Most people are familiar with the so-called "leaky hearts" of children, due to rheumatism, tonsillitis and other kindred infections, and for the prevention of such conditions scores of thousands of tonsils are removed every year. With these we are not concerned to-day.

What is the usual heart disease of middle age? How is it produced, and how recognized? How prevented? You must understand that the essential part of the heart is the heart muscle, which by its contraction produces the force which causes the blood to circulate. The one thing, which is all-important, is to keep this muscle in its best possible condition, so that it may stand up under the work it has to do, twenty-four hours in every day. Now the causes of a diseased heart muscle are many. They are not spectacular, and do not operate quickly. On the contrary, they are, at first sight,

insignificant, but it must be borne in mind that they operate over long periods of time.

To begin with, a muscle should be exercised regularly. Imagine an athlete preparing to enter a contest who did not exercise regularly. A heart muscle which is not regularly exercised becomes flabby, weak, poorly nourished, and in the course of years, becomes unable to fulfil its duty. Hence the necessity of men and women taking regular exercise of a kind and degree suited to their needs. The advent of the motor car, by making physical exercise more and more difficult, is contributing its share toward bad hearts. On the other hand, a heart muscle, like any other muscle, may be overstrained. The hard-working business or professional man, who takes little or no exercise in his daily life, and then goes to the woods or mountains for two or three weeks a year, and subjects himself to inordinate fatigue and strain, is apt to do himself more harm than good. It is the steady, moderate, daily exercise that keeps a heart and indeed all the muscles in good condition. Another frequent event of middle life, with its lessened physical activity, is the tendency to take on excess weight. Every useless pound the heart has to supply with blood means that much more of a strain. Here, too, there is a reverse side of the picture, for many people, in their efforts to grow thin, get themselves into a condition of poor nutrition, which again weakens their long-suffering hearts. Anemia, due in large measure to an injudicious diet, lacking in iron, is one of our commonest conditions, and the lack of this important element in the blood is a further cause of the heart's degeneration.

High blood pressure, due to a variety of causes, is a potent cause of chronic heart failure. To be emphasized is the fact that these apparently small causes, acting over a period of years, produce dangerous and perhaps ultimately fatal results. Now how does a heart of this kind behave? What symptoms does it produce? First, bodily fatigue. The individual finds himself unable to stand exertion as he formerly did. He lacks "pick-up," as a motorist would say. A walk of a mile or two at a fair gait becomes a thing to be dreaded, not enjoyed. How general this condition of things was abundantly shown by the medical reports of the World War, which disclosed a rather discouraging state of things in young recruits, and this has certainly not improved in the intervening years. A little later, shortness of breath appears, perhaps just on climbing stairs. This means again that the heart is not quite up to its work, and the breathlessness is a sign to stop. These two symptoms, unaccountable fatigue and shortness of breath, should make every middle-aged person pause and reflect, and then subject himself to a careful looking over.

More advanced symptoms are discomfort or tenderness in the upper abdomen, due to congestion, and it is quite common to have patients present themselves for examination for supposed stomach trouble, who have in reality, a heart that is breaking down. Still later, the ankles swell, become "puffy," as we say. There is a common idea that this is a very early symptom of heart failure, whereas, it is in reality an indication that it has already existed for a considerable period of time, and is probably progressing. You should know that also in such conditions as varicose veins, the legs may swell up without any heart condition being present, but these are evident to even a casual inspection. When, however, the legs begin to swell, and there is increased bodily fatigue and shortness of breath, it means that you should have a careful examination and appropriate advice at once. The medical profession has been endeavoring for a long time to have people go to their family physician at regular intervals for

a complete examination, just as many now go to their dentist. Certainly, as middle age approaches, this is only the part of prudence.

Every one is familiar with the pathetic picture of the far-advanced patient with heart trouble—unable to lie down to sleep, with the lower part of his body swollen with the dropsy, often gasping for breath and leading an utterly wretched existence for months before his end. Let us concentrate on this one vital point, namely, that the prevention of heart disease is vastly simpler and more important than its cure.

What can an individual of perhaps forty years of age do to prevent such a state of affairs? First of all, a fair amount of exercise for the heart, which means, of course, physical exercise. Walking is easily the best form of physical exercise in middle age, because it can be done every day in the year, and requires no special equipment and not even a companion. A still more important reason is that there is not the same tendency to overdo matters, as so often happens in athletics. We might well imitate our British cousins in this respect, for they are born walkers. Many a man would do well to forget his motor car and walk to and from his office daily.

At forty many men and still more frequently women are liable to take on excess weight. This is entirely unnecessary, since in the hands of a competent physician a normal individual can control his weight under proper medical advice. On the other hand, if already over weight, do not experiment on your own initiative with diet, but consult your physician and be sure to take his advice. Another factor of importance is to secure abundant sleep. Researches conducted in the last two years have shown the great importance of sunlight to health, which means that one should not read or play bridge until the wee small hours of the morning and then get up late, for by so doing one shortens appreciably the hours of sunlight. Modern science has conclusively shown the truth of the old adage, "Early to bed and early to rise."

We hear a great deal of men breaking ing down physically from overwork, and possibly occasionally one does. On the other hand, men stand up under tremendous work for decades and are none the worse for it. One of the greatest medical men, who himself lived to a ripe old age and accomplished an enormous amount of investigative work, summed up his philosophy of life in these words, "That it is worry and not work that kills the man."

We hear much of the span of life growing longer. This is true, but it is only true because we are saving more babies and children to grow up to adult life. On the other hand, fewer men of sixty reach the age of seventy now than did many years ago, and heart disease is one of the causes for this. The difficult thing for people to realize is that the degenerative heart diseases are in a large measure a product of an unwise mode of life, along the lines I have already mentioned. If we would all take regular, moderate exercise, eat a balanced diet, adequate in all respects, secure abundant sleep, stop carrying the weight of the world on our shoulders and have our own motor inspected by a competent physician at systematic intervals, we would go a considerable way towards making the sixties extend to the Biblical three score and ten.

DRAGONFLY HUNTING IN OKLAHOMA

By Dr. RALPH D. BIRD

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It was one of those glorious May afternoons with a brilliantly blue sky, white fleecy clouds and warm sun, not too hot, one of those days which irresistibly draws one out of doors to bask in the sun and enjoy the glory of nature, that I took my insect net and camera and went dragon hunting.

A "bug-hunter" like myself finds that the ways in which insects behave form a fascinating study. When a group is chosen whose members combine beauty of form and color, interesting life histories, comparative abundance, activity of flight and moderate difficulty of capture, this study is especially interesting. Such a group is the Odonata, composed of the large, strong-flying dragonflies and the weaker, smaller damselflies which are to be found about nearly every pond, marsh or stream.

The thrill of a successful catch, when one of the big fellows falls prey to a powerful, well-directed sweep of the net, is comparable to that experienced by sportsmen in dropping a duck or pulling out a gamey bass. Even more satisfying is the pleasure afforded by a good negative after one carefully stalks and snaps a photograph of one of the wary dragons, or when by watchful waiting in the early morning hours one gets a good series of pictures on the emergence and transformance of a brown, sluggish nymph into a splendidly winged, strong-flying creature.

The place where I chose to collect was a small marshy tributary on the west bank of the South Canadian River in central Oklahoma. Although in heavy rains it is a slow stream, it was now stagnant with a black, oozy bottom under two or three feet of muddy water. No trees nor bushes surrounded the marsh, but a heavy growth of rushes formed a fringe about the edge and grew out a few feet into the water. Yellow masses of filamentous algae, held up by bubbles of liberated oxygen, floated in the shallower places.

As I approached I could see large dragonflies darting here and there. Some of the first to attract my attention were several males of the white-tail skimmer, *Plathemis lydia*, actively flying back and forth close to the shore. A dazzling white abdomen, covered by a thick waxy pruinescence, resembling the bloom on a ripe plum, made them conspicuous, despite their moderate size. A somber blackish female, busily occupied in laying eggs, tried to slip by and avoid the attentions of the overjealous males. She lacked pruinescence and had a black tip as well as bar to her wings. Her ovipositing was simply accomplished by dipping down and tapping the water with the tip of her abdomen to wash off the eggs as they were exuded. I caught her with the net, and by twisting her head round a turn and a half, made her pose for the camera on the back of my drawing board (Fig. 1).

Out over the open water were some large reddish dragonflies, *Tramea onusta*, with conspicuous broad bars of the same color across the base of their wings. This gave their movements the appearance of the fluttering flight of a butterfly. A few individuals of another species, *Tramea lacerata*, were similarly marked with black instead of red. A pair of *Tramea onusta* came flying past in tandem, the male holding the back of the female's head by means of the claspers at the tip of his abdomen. He

FIG. 1. A DRAGONFLY, *Plathemis lydia*.[1]

assisted his less brightly colored mate while she was ovipositing. When they reached a favorable egg-laying location, they paused for a fraction of a second about a foot above the surface. Almost quicker than the eye could follow, he released his hold, she dipped down to touch the water with the tip of her abdomen, rose, was grasped by the male and away they flew to repeat the operation at another place.

Sometimes solitary individuals would fly about a foot above the water close to the fringe of rushes, hovering in the quieter spots for a second or less. So engaged, they were distinctly seen to catch small insects in flight.

While I watched the hovering Trameas, a big dragon, giant of them all, came darting rapidly past. His bright blue abdomen, marked with a dorsal brown stripe, green thorax and clear wings distinguished him as the male of the green darter, *Anax junius*. He did not have the fluttering flight of the Trameas, but flew in a more or less straight line close to the rushes or out over the open water, occasionally hovering and catching an insect in flight by swooping it up from below in the manner of a fish rising to the bait. His six spiny legs were held to form a basket to catch the luckless mosquitoes and smaller fry. Later, he was seen flying in tandem with his duller but similarly marked mate. This species oviposited in tandem by alighting for a few seconds on dead floating rushes or cattails, while the female made a few stabs below water into the tissues of the plants with her ovipositor and inserted her eggs. These strong-flying individuals are often seen hunting over fields miles from water. They are difficult to capture with a net, but by watching them for a few minutes I could generally find that they regularly passed along a favored stretch of shore or along a narrow neck of water. By waiting there with a ready net, they could be taken with a swift sweep from behind, never from in front, for they would surely dodge. A rustle of wings in the net told of a successful sweep. It was not as easy as it looked and there was a good deal of sport connected with catching them.

On approaching the pond, my attention was at first drawn to the larger species, but at I looked more closely at the water I saw myriads of exquisitely beautiful little damselflies. The two commonest species, *Enallagma civile* and *Enallagma basidens*, were an azure blue with black markings. The former was the larger of the two, but without examining them in the hand they looked much the same and were found closely associated. Some were sitting low on rushes, all facing into the wind. Three or four might be perched one above another on an upright rush, like so many pennant flags. Others were flying out over the open pond so low that they almost touched the surface, always facing into the wind as fish would face the current in the stream, and taking quick flights down the wind only to regain their position. This habit was indulged in more by *Enallagma civile* than by the smaller and weaker *Enallagma basidens*. These activities were followed mostly by the unmated males, which always appeared much more abundant than the females. Practically all females ob-

[1] The photographs in this article were taken by the author in May, 1932.

served were in tandem with a male and spent most of their time egg-laying.

The floating masses of filamentous algae appeared to be favored for ovipositing. There were a dozen or more pairs in a patch not over a yard square (Fig. 2). They would alight on the algae, the female first holding the abdomen out horizontally or slightly elevated, but in a few seconds she would start to oviposit by bending her abdomen down into the algae and immersing it for about half its length, probing about, inserting her eggs with the ovipositor. The male meanwhile either tried to balance himself at an angle of about forty-five degrees or let himself down and hung on the algae with his body parallel to the water surface. He would continually flutter his wings and either fold his legs close to the body or let one or two dangle. The pair would remain in one place for a minute or two at a time.

Associating with their blue and black cousins were a few orange and black *Enallagma signatum*, which blended so closely with the algal color that they were difficult to distinguish. There were both solitary males and tandem pairs. Occasionally they would take short flights out over the open water, flying very close to the surface. The males were pugnacious and chased each other and the more abundant *Enallagmas* when they ventured too close.

The main activity of the tandem pairs was ovipositing. One pair which I watched and timed was particularly interesting. They lit on top of a pond weed, and the female began at once probing about below the surface with her ovipositor while the male balanced himself as best he could. He kept his legs and wings folded and his body rigid. Finally he let himself down and hung on to a piece of floating algae. Meanwhile, his mate backed farther and farther down the stem until only her thorax was above water. She was apparently held up by the surface tension which bent the water film down into a distinct trough about her. At last it broke and she was completely submerged. Undaunted, she continued backing down until all but the thorax of the male, who still clung to his mate, was under water. After about ten minutes of egg-laying she came to the surface for a few minutes, never ceasing to probe about, then backed down again. At this time the

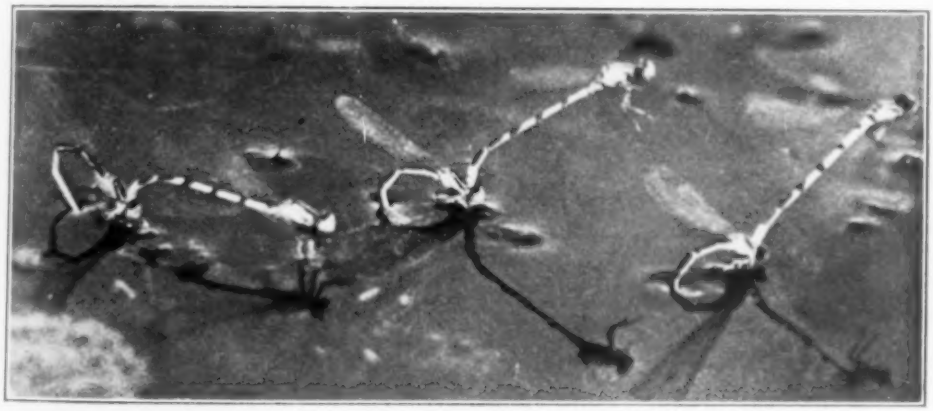

FIG. 2. THREE PAIRS OF OVIPOSITING DAMSELFLIES, *ENALLAGMA CIVILE*
THE MALE HOLDS THE FEMALE AT THE BACK OF HER NECK BY MEANS OF THE CLASPERS AT THE TIP OF HIS ABDOMEN. WHILE THE FEMALE IMMERSES HER OVIPOSITOR AND PROBES ABOUT LAYING EGGS, THE MALE SUPPORTS HIMSELF ON THE ALGAE OR BALANCES HIMSELF WITH FLUTTERING WINGS IN MID-AIR.

FIG. 3. POND ON THE BANKS OF THE SOUTH CANADIAN RIVER NEAR NORMAN, OKLAHOMA,

WHERE DRAGONFLIES AND DAMSELFLIES ARE COMMON. THE RUSHES IN THE FOREGROUND ARE FILLED WITH EGGS LAID BY *Lestes alacer*.

male, being annoyed by an *Enallagma civile* trying to sit on his head, deserting his partner, let go and flew away. She stayed down for about ten minutes more before coming up so that her thorax was above water. A male *Enallagma basidens* at once lit on her and tried unsuccessfully to take hold of the back of her neck. Thus bothered, she again went down, this time for fully twenty minutes, descending about two inches below the surface. She was visible all the time and could be seen thrusting about in the pond weed inserting eggs into the leaves. When she finally came up, her body moved by jerks, because, being lighter than water, when she loosed her hold, she would float up. A film of air could be seen about her thorax. Her body and wings did not appear to be wet after the submergence, and she flew off without difficulty when she reached the surface. She lit on a near-by rush where she carefully attended to her toilet of wiping off and polishing her body.

Flitting about among the rushes, scarcely daring to trust their feeble wings to the wind away from their shelters, were the exquisite little damsels, *Ischnura verticalis*. Their thorax was green and the tip of the abdomen blue, the rest black. The dark color was hardly visible against the background of the rushes, so that all one saw was two widely separated green and blue dots slipping along.

After studying, collecting and photographing here, I moved on to a pond at the head of the stagnant stream (Fig. 3). It had a hard bottom and a scattered growth of rushes about the edges. All the species seen at the other location were here, and in addition a number of larger, somber-colored damselflies, *Lestes alacer* and *Lestes forcipatus*. The for-

FIG. 4. A TANDEM PAIR OF *LESTES ALACER*

OVIPOSITING ON A RUSH ON THE SHORE ON THE POND IN FIG. 3. THE ROW OF EGGS MAY BE SEEN JUST BELOW THE FEMALE, SOMEWHAT OUT OF FOCUS BUT STILL VISIBLE.

mer were more abundant, but both had the same habit of egg-laying in the rushes well above water line. The many ovipositing pairs had filled practically every rush with eggs in irregular vertical rows two or three inches long. Females seemed to prefer to insert the eggs along the angle rather than along the flat side, although some were found in both places. Their presence was indicated by oval, whitish dots of dead tissue. I watched and photographed one pair as they worked (Fig. 4). The male would bend his abdomen into a semicircle and keep his tightly folded wings elevated. The female half spread her wings and bent her abdomen in almost a complete circle so that the ovipositor was almost touching her thorax. She would lay a number of eggs without changing her position. After ovipositing on one side for about five minutes, she shifted to the opposite side of the rush, continued for another five minutes and then flew away.

Clinging to a number of rushes were the brown cast-off skins or exuviae left when the immature dragonflies and damselflies moulted for the last time to become adult. Dragonflies spend their early stages under water as inconspicuous nymphs, obtaining oxygen from the water by means of gills, and living on small aquatic animals. Mosquito larvae are their favorite food, although some of the large nymphs will attack tadpoles and even small fish. After a life of a year or more, during which they moult a number of times, they climb out of the water and shed their skin the last time to become adult. This emergence and transformation takes place early in the morning, so a few days later I went out and was lucky enough to observe the change in both *Enallagma civile* and in a dragonfly, *Gomphus militaris*.

It is during the few hours of emergence and the time shortly afterward

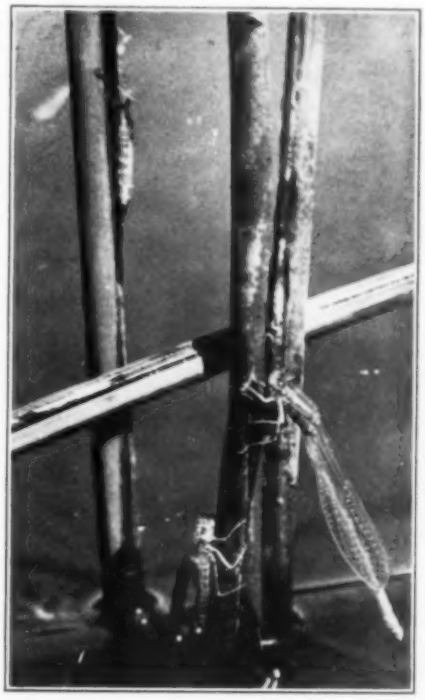

FIG. 5. EMERGENCE OF *ENALLAGMA CIVILE*

THE EXUVIAE IS IN THE LOWER LEFT AND THE NEWLY EMERGED ADULT AT RIGHT. THE EXUVIAE OF ANOTHER INDIVIDUAL IS AT THE UPPER LEFT.

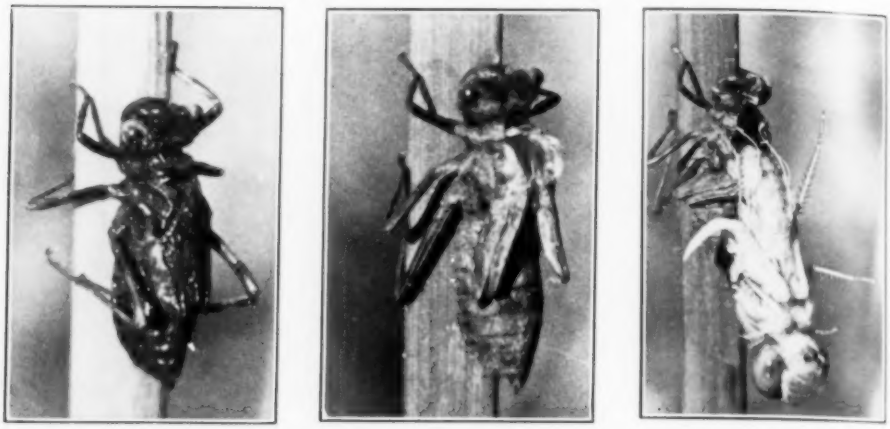

FIG. 6. EMERGENCE OF *SYMPETRUM CORRUPTUM*

LEFT. THE NYMPH, STILL WET AND SHINY, FIRMLY GRASPS THE RUSH. CENTER. THE SKIN SPLITS AT THE BACK OF THE THORAX. RIGHT. THE PARTIALLY EMERGED ADULT, STILL TOO WEAK TO PULL ITSELF TO AN ERECT POSITION, HANGS HEAD DOWNWARD BY THE TIP OF THE ABDOMEN STILL ENCLOSED IN THE NYMPHAL SKIN.

that these insects are in their greatest danger from enemies. At this period their bodies are soft and the unexpanded wings are incapable of flight. The helpless dragonflies are frequently overpowered by swarms of ants or waiting spiders. Birds gobble them up in great numbers as the weak adults flutter feebly from their exuviae to the near-by vegetation.

On the morning of May 10, great numbers of *Enallagma civile* were emerging between seven and eight o'clock. At this time of day the water was much warmer than the air. The nymphs would crawl up the rushes growing in shallow water close to shore. The one which I watched particularly in all stages of its emergence, from the time it left the water at 6:52 A. M. until it flew at 8:20, behaved as follows:

The larva crawled up the rush about an inch above the water and took a firm hold by embracing it as closely as possible with its legs. It was at first wet and shiny but soon dried. After seventeen minutes the skin cracked between its shoulders and at the back of the head. The thorax was the first to emerge; then the head and legs. It stood out from the stem supported only by the end of the abdomen, which was still in the exuviae. After a pause of nine minutes, during which time it gained strength, it reached down, grasped the exuviae with its legs and pulled out its abdomen. Now free from its moulted skin, but still soft and colorless, it moved to the sunny side of the rush and could soon see well enough to react to my movements a foot or more away. The abdomen, at first longer than the wings, was short and compact. The wings were literally blown out, as one would blow out a toy balloon, with the tips being the last to expand. Half an hour after the time when the skin began to crack the wings were completely expanded and had become three sixteenths of an inch longer than the abdomen. The abdomen then began to grow and telescope out with a sort of pumping action. In about an hour it was a quarter of an inch longer than the wings (Fig. 5). Five or six drops of a clear liquid were expelled. After resting and gaining strength, the insect cleaned its face by rubbing with its front legs. Ninety

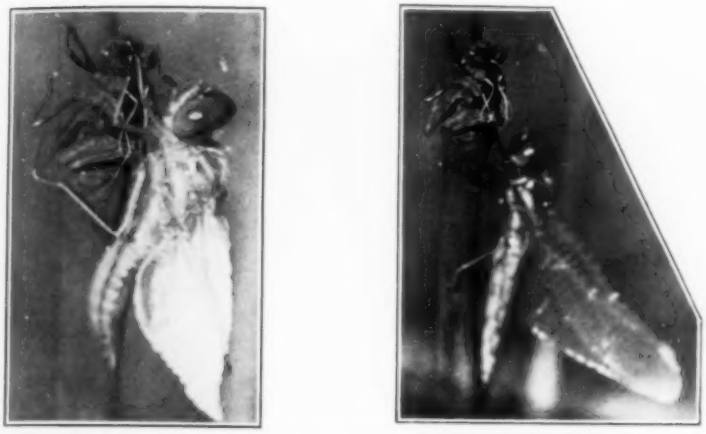

FIG. 7. EMERGENCE OF *SYMPETRUM CORRUPTUM*

LEFT. THE ADULT HAS PULLED ITSELF FREE FROM THE EXUVIAE TO WHICH IT STILL CLINGS. THE WINGS BEGIN TO EXPAND BUT ARE MILKY AND WRINKLED AT THE TIPS. RIGHT. THE ADULT HAS MOVED PARTLY OUT OF FOCUS. WINGS AND ABDOMEN ARE BEING EXPANDED. THE WINGS AT THIS STAGE ARE LONGER THAN THE ABDOMEN.

minutes after the skin cracked it flew to the vegetation back from the pond. At this stage it was termed a teneral. It would not gain full coloration for several days.

I had hardly finished making observations on the *Enallagma* when I saw the nymph of a dragonfly, *Gomphus militaris*, crawling in very shallow water. It crawled out of the water, but, apparently finding conditions unsatisfactory, would return. It spent about a quarter of an hour looking for a place to transform and finally came to rest with only its back above water. Here it went through much the same changes as did *Enallagma civile*, except that, being flat on the ground, it first stood erect on its abdomen.

On this particular morning, I was too late to observe the emergence of some of the other species, so a week later I returned to the pond, this time at 5:50 A. M. The sun was just up and a heavy mist was arising from the water. Even at this early hour I found I was too late for the emergence of *Anax junius*, for I saw three completely developed tenerals ready to fly from their exuviae. Another specimen, not so fortunate, had been overpowered and killed by a swarm of small yellow ants.

My early trip was not in vain, for at 6:40 I found a wet and shiny nymph of *Sympetrum corruptum*, which had just crawled up a rush about six inches above the water. I had plenty of time to set up the camera and make myself comfortable for taking pictures and notes. This species took two hours for its complete emergence. It differed from the others I had watched in that when it had pulled its head and thorax from the larval skin, it was too weak to pull itself up and had to hang head downward by the tip of its abdomen for at least fifteen minutes. The accompanying illustrations (Figs. 6 and 7), show how a squat, compact, aquatic creature changes into a graceful being ready to soar away and conquer a new element, the air.

Such are the experiences of a modern dragon hunter—perhaps not as exciting as those of the fabled knights of old, but thrilling to those in search of the scientific adventures which may be found close to home.

PROFESSOR HUGO DE VRIES

THE PROGRESS OF SCIENCE

THE WORK OF PROFESSOR HUGO DE VRIES

On February 16 last, Hugo de Vries, the Dutch botanist, celebrated his eighty-fifth birthday. To few living scientists has it been the lot to have influenced so profoundly the theory and experimental practise in their chosen fields. He was able to bring to bear upon his investigations a combination of mental qualities which are rarely found developed to the same degree in a single individual. He has been a keen observer, a patient accumulator of data, an energetic experimenter, skilful in interpretation of evidence and yet able to relate his findings to broader problems. He has been a man of theory and vision as well as a gatherer of details in laboratory and garden.

De Vries was born at Haarlem, Holland, in 1848. He received his doctorate from the University of Leiden in 1870 with the thesis entitled "The Influence of Heat on Life Phenomena in Plants." Later he studied in the German universities of Heidelberg and Wurzburg and at the latter university and at Halle carried on investigations for the German Department of Agriculture. In 1877 he came to the University of Amsterdam as lecturer in plant physiology, where he eventually became professor of plant physiology. He retired in 1918 and since then has lived in Lunteren, Holland, where he has a small greenhouse and an experimental garden in which he still continues his studies on the evening primroses.

De Vries has always been classified as a botanist, but his early work on the causes of turgor in plants has had important influence on the development of theories in chemistry. He extended the plasmolytic method as a means of determining the osmotic pressures exerted by the sap within living cells. He thus determined the relative influence of molecular solutions of different salts and organic compounds upon osmotic pressure and expressed these differences in terms of his isotonic coefficients. Upon these studies, Van't Hoff and Arrhenius based their laws of dissociation in dilute solutions which form one of the fundamental concepts of modern physical chemistry.

De Vries is most widely known for his influence on biological thought. In 1889 he presented his theory of intracellular pangenesis in which, on the basis of extensive observations, he argued for the existence of hereditary particles in all cells corresponding to the different characters in the organism. He thus early visioned our modern concept of the gene. Strasburger, in his foreword to Gager's translation of "Intracellular Pangenesis," writes as follows: "By creative imagination Hugo de Vries predicted much in his book that gained a material basis only through the histological research of the following decades . . . he predicted phenomena which were to furnish the basis for our conceptions of fertilization and heredity but which have become actually known to us only through later works on the most intimate processes of nuclear division." His powers of prophetic imagination are also shown in an address entitled "The Aim of Experimental Evolution," which was delivered at the opening of the Station for Experimental Evolution in 1904.[1] He urged that attempts be made to alter the hereditary particles in the germ cells by different kinds of external stimuli. He pointed out that x-rays and radium have proved themselves capable of provoking important changes in living organisms. "If the same holds good for our dormant representatives in the egg," he said, "we may hope some day to apply

[1] This address is published in the third Yearbook of the Carnegie Institution of Washington, but does not appear in the reprint series of de Vries' papers, "Opera e Periodicis Collata."

the physiological activity of the rays of Röntgen and Curie to experimental morphology." It was nearly a quarter of a century before this hope was realized.

De Vries was one of the three wise men of the eastern hemisphere who in 1900 independently rediscovered Mendel's law of inheritance and thus dated the beginning of the modern science of genetics.

His greatest influence on biology has come from his mutation theory, presented in two volumes in 1901 and 1903. This was supported by a wealth of observation and experiments. His idea that normal evolution is by sudden jumps rather than by gradual change and that evolution can be observed experimentally was a tremendous stimulus to scientific experiments in plant and animal breeding. Darwin was a good botanical experimenter, but his followers seem to have favored observation and speculation. De Vries' greatest service to biology has been in making experimentation the basis of evolutionary theories.

The Evening Primrose (*Oenothera Lamarckiana*), flowers of which he is holding in his hands in the photograph, has been the object of his investigation during all his later years. In 1886 he found plants of this species growing in a field near Hilversum, Holland, and among them a number of variants. He believed he had found a species which was in a stage of rapid evolution and mutating off "elementary species." For about a decade he carried on investigations on these Oenotheras in secret before publishing his results. They formed the main support for his mutation theory. Many other investigators have since taken up the study of Oenotheras, and the literature on the genetics of the genus has reached an enormous volume. The mutations which the Evening Primroses produce in such relatively large numbers are not now thought to be elementary species in quite the sense that de Vries first believed, but this fact need not detract from the value of the mutation theory to which they gave rise. The Oenothera investigations have given us information on a type of inheritance and genetic change that is more common than was once supposed. They are still giving us information about the origin of species.

We wish many more years to the genial grand old man of Lunteren, but the name of Hugo de Vries will always live as that of one of the master minds of science.

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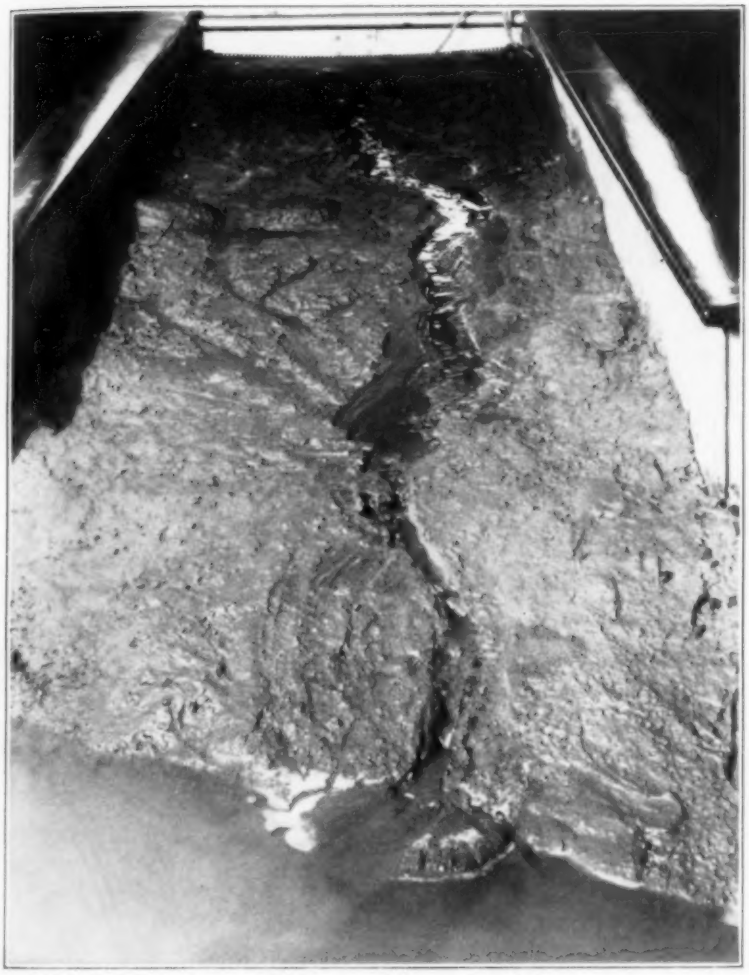
THE EARTH SCIENCES AT A CENTURY OF PROGRESS

EXHIBITS descriptive of a century's advance in the earth sciences will form an integral part of the displays in the Basic Sciences Division of Chicago's 1933 "Century of Progress" Exposition, the general features of which were described by Professor Henry Crew in the September issue of the SCIENTIFIC MONTHLY under the title "Exposition of Science."

The earth sciences, comprising such fields as geography, cartography, physiography, meteorology, mineralogy, physical, historical and economic geology, have played an important rôle in the development of our modern industrialism. Indeed, with physics and chemistry, they have largely sponsored the "technical ascent of man." To cite only a few examples, meteorology has made possible weather forecasting and man's commercial conquest of the air; geography and cartography are responsible for his knowledge of the face of the globe and his varied, planned adaptations to its physical features and climatic zones; and to geology goes much of the credit for making available raw



STREAM TABLE EROSIONAL AREAS WITH SPRINKLER REMOVED

THE STREAM IS FED BY THE FLOW FROM BURIED RUBBER TUBES. THE REGION IN THE MID-AREA OF THE PHOTOGRAPH HAS BEEN SLIGHTLY IMPOUNDED AND THE GRADIENT INCREASED DOWNSTREAM, WHERE, AS A CONSEQUENCE, RAPIDS HAVE FORMED.

materials upon which our present economic structure is based. One hundred years ago the United States produced no petroleum, practically no lead, zinc or copper, and only insignificant quantities of iron and coal. Indeed so little gold was mined at that time that our total per capita amount was only about three cents. To-day, owing to great advances in the science of geology and the profession of geological engineering, practically all the mineral resources of the country have become known, and the normal production of most of our raw materials goes on at a rate which is almost incomprehensible.

The direct social consequences of the geologist's development of the petroleum and other mineral resources of the world are far-reaching and commonplace. But, equally important and less well known is the fact that geology develops an appreciation of the enormous duration of time involved in the gradual evolution

THE HALL OF SCIENCE OF A CENTURY OF PROGRESS

THE EARTH SCIENCES EXHIBITS ARE HOUSED NEAR THE MAIN ENTRANCE IN THE RIGHT WING OF THE BUILDING.

DIORAMA OF A BATTLE BETWEEN THE THREE-HORNED TRICERATOPS AND TYRANNOSAURUS

CRETACEOUS DINOSAURS WHICH LIVED ABOUT ONE HUNDRED MILLION YEARS AGO IN THE AREA WHICH NOW MAKES UP OUR WESTERN PLAINS.

of the earth and its inhabitants. It demonstrates the continuity of the past and the present, and furnishes the background for an understanding of man's origin and his present place in nature. Geology also deepens man's esthetic appreciation of scenic wonders through imparting a knowledge of the processes through which the great physical features of the earth have originated.

Much of this information is, of course, well known to the technically trained citizen, but most of the facts have never been fully realized by the "man in the street."

The Section of the Earth Sciences at A Century of Progress will appropriately feature, therefore, a "giant clock of the ages," which will be shown ticking off the eons involved in earth history. All the two billion years or more of this epic account will be seen on the clock dial as occurring in one conventional hour, although the "minute hand" will actually complete its "hour" circuit in about four minutes. As the rapidly moving "minute hand" reaches successive points of great geological interest, an appropriate sequence of geological scenes will appear on the screen in the center of the dial, and each scene will be described by means of a synchronized phonographic record.

But although the "clock of ages" will strike the keynote of the earth sciences' story at A Century of Progress, there will be a wealth of dynamic individual exhibits calculated to tell completely and intimately the complicated story of the origin and growth of our own planet. Space does not suffice for a detailed account of these exhibits, but the visitor will see, for instance, animated displays showing the processes of erosion and deposition which have so largely shaped the face of the earth. These processes acting very slowly in nature will be shown in greatly accelerated fashion in a mechanical device known as a stream table. Dioramas, or three-dimensional pictures, showing some of the animals of the past, will form a part of the section on paleontology, in which the main theme will be the life of former geological periods. The visitor will also find operating models demonstrating the formation of mountain ranges, the growth and activities of volcanoes and the eruption of geysers; and he will be initiated into the mysteries of earthquakes and the manner in which man has forced them to write their own records. A group of important displays of similar type, representing earth features as exemplified in our national parks, such as the Yellowstone geysers, Bryce, Yosemite

and Grand canyons, Carlsbad caverns and Kilauea crater, are being built by the National Park Service.

The origin, accumulation and migration of oil and gas will be completely demonstrated in a great sequence of operating exhibits sponsored by the American Petroleum Industries. These exhibits, many of which are already constructed, cover every phase of oil and gas production. Other displays will explain man's modern, almost magical, methods of locating the deeply buried metallic and non-metallic products, and the methods used by him in winning these raw products from the earth.

In short, while the Century of Progress will dramatize the last hundred years of man's scientific advance, the displays in the earth sciences will attempt to vitalize for the public the many millions of years involved in the earth's history. Furthermore, they will point out, in simple fashion, just how and why the earth is continually changing its facial expression, they will call attention to the many strange animals and plants which it has nourished, and they will explain the origin and distribution of its great mineral resources.

CAREY CRONEIS
In Charge of Geology Section

DR. GEORGE O. CURME, JR., RECIPIENT OF THE CHANDLER MEDAL

THE Chandler Medal was presented to Dr. George O. Curme, Jr., on March 17 at Columbia University, for his notable contributions to the advancement of the applications of chemistry to industry. Dr. Curme carried out his graduate work at Northwestern University, the University of Chicago and in Berlin. He has been associated with the Union Carbide and Carbon Corporation since 1914 and is now vice-president and director of research of the Carbide and Carbon Chemicals Corporation.

Dr. Arthur W. Hixson, professor of chemical engineering at Columbia University, and chairman of the award committee, in commenting on Dr. Curme's work said:

"Although the achievements of Dr. Curme are only now beginning to be recognized, it is of significant importance that his ideas and his thoughts as expressed to his intimate friends have changed but little in the fifteen years that have elapsed since he began this work. He saw clearly in 1915 and 1916, before anybody else appreciated the possibilities, just exactly what is happening to-day in the field of aliphatic chemistry and he predicted in those days the industrial use of these aliphatic compounds in quantities reaching into the millions of pounds per month, although at the time only test-tube quantities were available.

"The achievements of Dr. Curme are many. His original work involved the production of acetylene, the thermo-decomposition of mineral oil inducted by sticking an electric arc beneath the surface of the oil. This was done in 1915–16.

"Subsequently he has worked out practical methods for the production of ethylene glycol, ethylene dichloride, ethylene chlorhydrin, ethylene oxide, diethyl sulfate, dichlor ethyl ether and many other compounds. Most of this work has been patented.

"Dr. Curme's greatest achievement has not been solely the working out of laboratory methods for making the compounds mentioned above, but in translating these laboratory applications to large-scale manufacturing processes. As is well known to-day, the production of ethylene glycol, ethylene dichloride, ethylene chlorhydrin and some of the other compounds mentioned runs into many millions of pounds annually.

"More recently his early work in connection with the production of synthetic isopropyl alcohol and acetone has been

DR. GEORGE O. CURME, JR.

commercialized and these products are now available on a large scale. He is considered one of the greatest living exponents of aliphatic chemistry.

"The achievement that has attracted the most public interest has been the manufacture of synthetic ethyl alcohol, which was put into production in a large way during April, 1930, but the preliminary work for it had been done and the process well outlined over ten years ago."

The Chandler Medal and Lectureship were instituted in 1910 by friends of the late Professor Charles Frederick Chandler, of Columbia University, pioneer in industrial chemistry and a founder of the American Chemical Society.

THE METRIC SYSTEM IN TRACK AND FIELD EVENTS

On November 22, 1932, the Amateur Athletic Union "went metric." It may, perhaps, be interesting to inquire what effect this action by the Union will be likely to have upon athletic events, and records in those countries in which, up to this time, distances for such events have very generally been expressed in yards, feet and inches.

First of all, it should be pointed out that from the standpoint of measurement athletic events fall into two general

classes—first, field events in which measurements of distance only are involved; and second, track events, in which measurements of distance and time are involved. The high-jump, broad-jump, pole vault, shot-put, discus-throw, hammer-throw, etc., fall within the first class, while the dashes, hurdles and other running events, of course, fall within the second class.

It is evident that field events will not be greatly affected by the adoption of the metric system of measurement. In all such events the height or distance attained by the contestant, whether measured in feet, inches and fractions of an inch, or in meters and fractions of a meter, can readily be converted from one system of measurement to the other. Records of past performances can also be readily converted. All that is needed is a convenient and accurate table of equivalents.

When we consider track events, however, we find a quite different situation. In these events standard distances are set up, in terms of a unit of length, either the yard or the meter, and the contest in each event consists in running this standard distance in a minimum time.

The standard distance chosen for each event is some integral number of yards or of meters, depending upon the system of measurement employed. For example, 100 yds., 220 yds., 440 yds., etc., or 100 meters, 110 meters, 200 meters, 400 meters, etc.

Obviously, the distances set up for a series of events under one system of measurement will not be appropriate for a series of similar events under the other system of measurement. Two entirely different series of distances will therefore be necessary, and it will not be possible to set up a table of equivalents for track events held under the two systems of measurement; and records made under the two systems will not be comparable. They represent, in fact, an entirely different series of events.

It may reasonably be assumed that other athletic organizations will follow the lead of the Amateur Athletic Union in adopting metric distances, and, with the above situation in mind, a question naturally arises as to what is likely to happen with reference to track records, for distances measured in yards, that are now on the books, if and when these events are no longer run.

Obviously, if the events are no longer run the present records can not be broken and will stand indefinitely. Such a record will, no doubt, when no longer subject to assault, lose some of its significance and relative value. To that extent the change can hardly fail to involve some disappointment to present record holders for distance events measured in yards. There is, however, a compensating advantage in that these records can not be broken and are therefore safe for all time, no matter how future athletes may "burn up the cinders."

In order that the layman, who is not entirely familiar with the metric system, may get the habit of thinking in terms of meters it may be well to give a few equivalents that will help to correlate some of the more important metric distances with the yard distances with which he is familiar:

Yards	Meters	Meters	Yards
50 =	45.72	50 =	54.68
100 =	91.44	100 =	109.36
120 =	109.73	110 =	120.30
220 =	201.17	200 =	218.72
440 =	402.34	300 =	328.08
880 =	804.67	400 =	437.44
(1 mile) 1760 =	1609.35	500 =	546.81
(2 miles) 3520 =	3218.69	800 =	874.89
		1000 =	1093.61
		1500 =	1640.42
		2000 =	2187.22
		3000 =	3280.83

Note: The above equivalents are approximate, but are correct to the number of decimal places given.

H. W. Bearce,
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National Bureau of Standards